PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 26 January 2001 (26.01.01)	
International application No. PCT/KR00/00633	**Applicant's or agent's file reference** SH-15000-PCT
International filing date (day/month/year) 15 June 2000 (15.06.00)	**Priority date** (day/month/year) 15 June 1999 (15.06.99)
Applicant KIM, Kwang-Chul	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

22 December 2000 (22.12.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer S. Mafla
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

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PATENT COOPERATION TREATY

PCT

REC'D 17 OCT 2001
WIPO PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Artcle 36 and Rule 70)

Applicant's or agent's file reference SH-15000-PCT	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. **PCT/KR00/00633**	International filing date *(day/month/year)* 15 JUNE 2000 (15.06.2000)	Priority date *(day/month/year)* 15 JUNE 1999 (15.06.1999)

International Patent Classification (IPC) or national classification and IPC

IPC7 H04J 11/00, H04L 7/00

Applicant

Samsung Electronics Co., Ltd. et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demamd	Date of completion of this report
22 DECEMBER 2000 (22.12.2000)	27 SEPTEMBER 2001 (27.09.2001)

Name and mailing address of the IPEA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, Dunsan-dong, Seo-gu, Daejeon Metropolitan City 302-701, Republic of Korea	JEONG, Yong Joo
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-5674

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International aplication No.
PCT/KR00/00633

I. Basis of the report

1. With regard to the elements of the international application:*

[X] the international application as originally filed

[ ] the description:
pages _____ , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

[ ] the claims:
pages _____ , as originally filed
pages _____ , as amended (together with any statment) under Article 19
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

[ ] the drawings:
pages _____ , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

[ ] the sequence listing part of the description:
pages _____ , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language English which is

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[X] the language of publication of the international application(under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide** and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

[ ] contained inthe international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disc losure in the international applicationas as filed has been furinshed.

[ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. [ ] The amendments have resulted in the cancellation of:

[ ] the description, pages _____

[ ] the claims, Nos. _____

[ ] the drawings, sheet _____

5. [ ] This opinion has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box(Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed." and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item I and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION

International aplication No.
PCT/KR00/00633

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-14	YES
	Claims		NO
Inventive step (IS)	Claims	1-14	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-14	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

Documents cited in the International Search Report :

A) JP 7-038,618

B) JP 7-297,870

C) US 5,555,247

D) JP 9-247,230

E) JP 10-004,401

The claimed invention relates to provide a frequency and symbol timing synchronization apparatus which can acquire more accurate frequency synchronization and more accurate symbol timing synchronization from an OFDM.

The claimed invention is not considered to be anticipated by the patent document cited. None of these documents reveals an autocorrelation unit for receiving data including a synchronizing symbol made up of at least three identical synchronization signals, a cross correlation unit.

The invention according to the claims 1-14 is therefore considered to be new, to involve an inventive step and to be industrially applicable.

02

RECORD COPY

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No. PCT/KR 00/00633

International Filing Date 14 June 2000 (14.06.00)

Name of receiving Office and "PCT International Application": Korean Industrial Property Office P C T International Application

Applicant's or agent's file reference *(if desired) (12 characters maximum)*: SH-15000-PCT

Box No. I TITLE OF INVENTION

SYMBOL TIMING AND FREQUENCY SYNCHRONIZING DEVICE FOR OFDM SIGNALS AND METHOD THEREOF

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

Samsung Electronics Co., Ltd.
416 Maetan-dong, Paldal-gu, Suwon-city, Kyungki-do
442-373 Republic of Korea

☐ This person is also inventor.

Telephone No.: (0331) 200-3608

Facsimile No.: (0331) 200-3455

Teleprinter No.:

State *(that is, country)* of nationality: KR

State *(that is, country)* of residence: KR

This person is applicant for the purposes of: ☐ all designated States ☑ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

KIM, Kwang-Chul

211-16 Chamshilbon-dong, Songpa-gu, Seoul
138-229 Republic of Korea

This person is:

☐ applicant only

☑ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: KR

State *(that is, country)* of residence: KR

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☑ the United States of America only ☐ the States indicated in the Supplemental Box

☑ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☑ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

LEE, Young-Pil

The Cheonghwa Bldg., 1571-18 Seocho-dong
Seocho-gu, Seoul, 137-073 Republic of Korea

Telephone No.: (02) 588-8585, 598-7211

Facsimile No.: (02) 588-8547/8

Teleprinter No.:

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Sheet No. 2 .....

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

SEO, Bo-Seok
12-804 Hanshin Apt., Doksan-dong, Keumcheon-gu
Seoul, 153-010 Republic of Korea

This person is:
- ☐ applicant only
- ☑ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: KR

State *(that is, country)* of residence: KR

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☑ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

- ☐ **AP** **ARIPO Patent:** **GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SL** Sierra Leone, **SZ** Swaziland, **TZ** United Republic of Tanzania, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☐ **EA** **Eurasian Patent:** **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☑ **EP** **European Patent:** **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☐ **OA** **OAPI Patent:** **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* . . . . . .

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

- ☐ **AE** United Arab Emirates
- ☐ **AL** Albania . . . . . .
- ☐ **AM** Armenia . . . . . .
- ☐ **AT** Austria . . . . . .
- ☐ **AU** Australia . . . . . .
- ☐ **AZ** Azerbaijan
- ☐ **BA** Bosnia and Herzegovina . . . . . .
- ☐ **BB** Barbados
- ☐ **BG** Bulgaria . . . . . .
- ☐ **BR** Brazil . . . . . .
- ☐ **BY** Belarus . . . . . .
- ☐ **CA** Canada
- ☐ **CH and LI** Switzerland and Liechtenstein
- ☑ **CN** China . . . . . .
- ☐ **CR** Costa Rica . . . . . .
- ☐ **CU** Cuba . . . . . .
- ☐ **CZ** Czech Republic . . . . . .
- ☐ **DE** Germany . . . . . .
- ☐ **DK** Denmark . . . . . .
- ☐ **DM** Dominica
- ☐ **EE** Estonia . . . . . .
- ☐ **ES** Spain . . . . . .
- ☐ **FI** Finland . . . . . .
- ☐ **GB** United Kingdom
- ☐ **GD** Grenada
- ☐ **GE** Georgia . . . . . .
- ☐ **GH** Ghana . . . . . .
- ☐ **GM** Gambia
- ☐ **HR** Croatia . . . . . .
- ☐ **HU** Hungary . . . . . .
- ☐ **ID** Indonesia
- ☐ **IL** Israel . . . . . .
- ☐ **IN** India . . . . . .
- ☐ **IS** Iceland
- ☑ **JP** Japan . . . . . .
- ☐ **KE** Kenya . . . . . .
- ☐ **KG** Kyrgyzstan . . . . . .
- ☐ **KP** Democratic People's Republic of Korea . . . . . .
- ☐ **KR** Republic of Korea . . . . . .
- ☐ **KZ** Kazakhstan . . . . . .
- ☐ **LC** Saint Lucia
- ☐ **LK** Sri Lanka
- ☐ **LR** Liberia
- ☐ **LS** Lesotho . . . . . .
- ☐ **LT** Lithuania
- ☐ **LU** Luxembourg
- ☐ **LV** Latvia
- ☐ **MA** Morocco . . . . . .
- ☐ **MD** Republic of Moldova . . . . . .
- ☐ **MG** Madagascar . . . . . .
- ☐ **MK** The former Yugoslav Republic of Macedonia . . . . . .
- ☐ **MN** Mongolia
- ☐ **MW** Malawi . . . . . .
- ☐ **MX** Mexico . . . . . .
- ☐ **NO** Norway
- ☐ **NZ** New Zealand . . . . . .
- ☐ **PL** Poland . . . . . .
- ☐ **PT** Portugal . . . . . .
- ☐ **RO** Romania
- ☐ **RU** Russian Federation . . . . . .
- ☐ **SD** Sudan
- ☐ **SE** Sweden
- ☐ **SG** Singapore
- ☐ **SI** Slovenia . . . . . .
- ☐ **SK** Slovakia . . . . . .
- ☐ **SL** Sierra Leone . . . . . .
- ☐ **TJ** Tajikistan . . . . . .
- ☐ **TM** Turkmenistan . . . . . .
- ☐ **TR** Turkey . . . . . .
- ☐ **TT** Trinidad and Tobago . . . . . .
- ☐ **TZ** United Republic of Tanzania
- ☐ **UA** Ukraine . . . . . .
- ☐ **UG** Uganda . . . . . .
- ☑ **US** United States of America . . . . . .
- ☐ **UZ** Uzbekistan . . . . . .
- ☐ **VN** Viet Nam . . . . . .
- ☐ **YU** Yugoslavia . . . . . .
- ☐ **ZA** South Africa . . . . . .
- ☐ **ZW** Zimbabwe . . . . . .

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

- ☐ . . . . . .
- ☐ . . . . . .

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 15 June 1999 (15.06.99)	1999-22297	KR		
item (2)				
item (3)				

☐ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s):

** Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)* : ISA / KR

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority)*:

Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	:	4
description (excluding sequence listing part)	:	6
claims	:	4
abstract	:	1
drawings	:	4
sequence listing part of description	:	
Total number of sheets	:	19

This international application is **accompanied by** the item(s) marked below:

1. ☑ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*:

Figure of the drawings which should accompany the abstract: FIG. 2

Language of filing of the international application: Korean

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

LEE, Young-Pil

For receiving Office use only

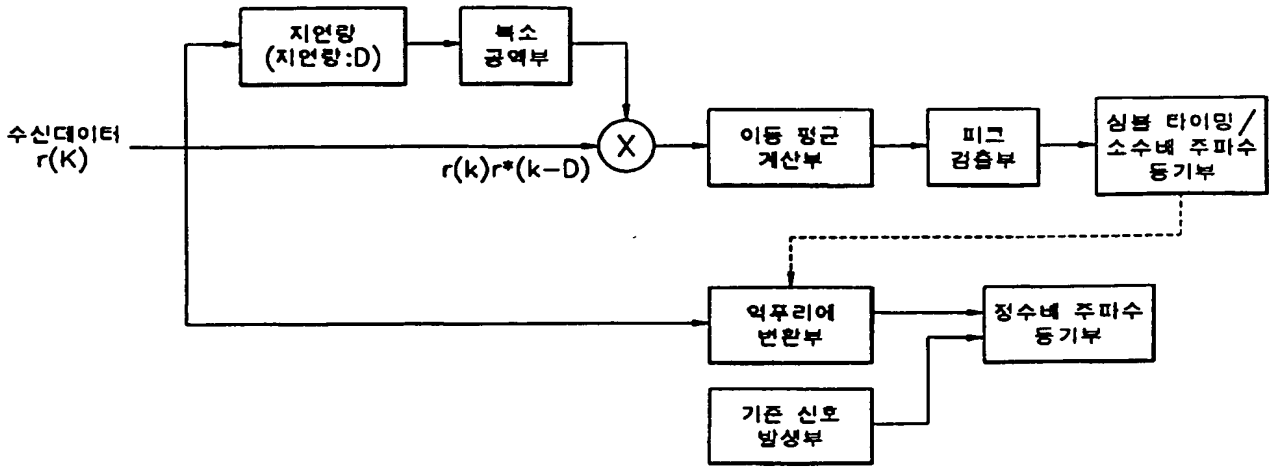
1. Date of actual receipt of the purported international application: 1st June 2000 (01.06.00)
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA / KR
6. ☐ Transmittal of search copy delayed until search fee is paid.

For International Bureau use only

Date of receipt of the record copy by the International Bureau: 28 JUNE 2000 (28.06.00)

【도면】

【도 1a】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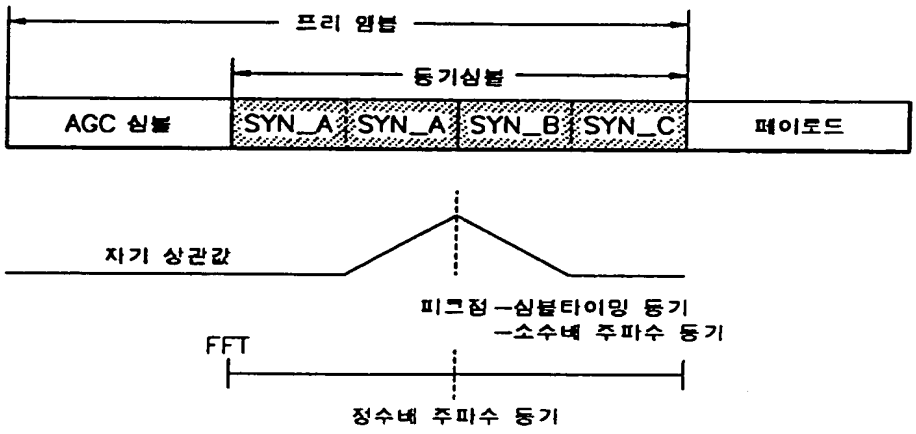
이동 평균
계산부
피크
검출부
심볼 타이밍/
소수배 주파수
동기부
역푸리에
변환부
정수배 주파수
동기부
기준 신호
발생부

【도 1b】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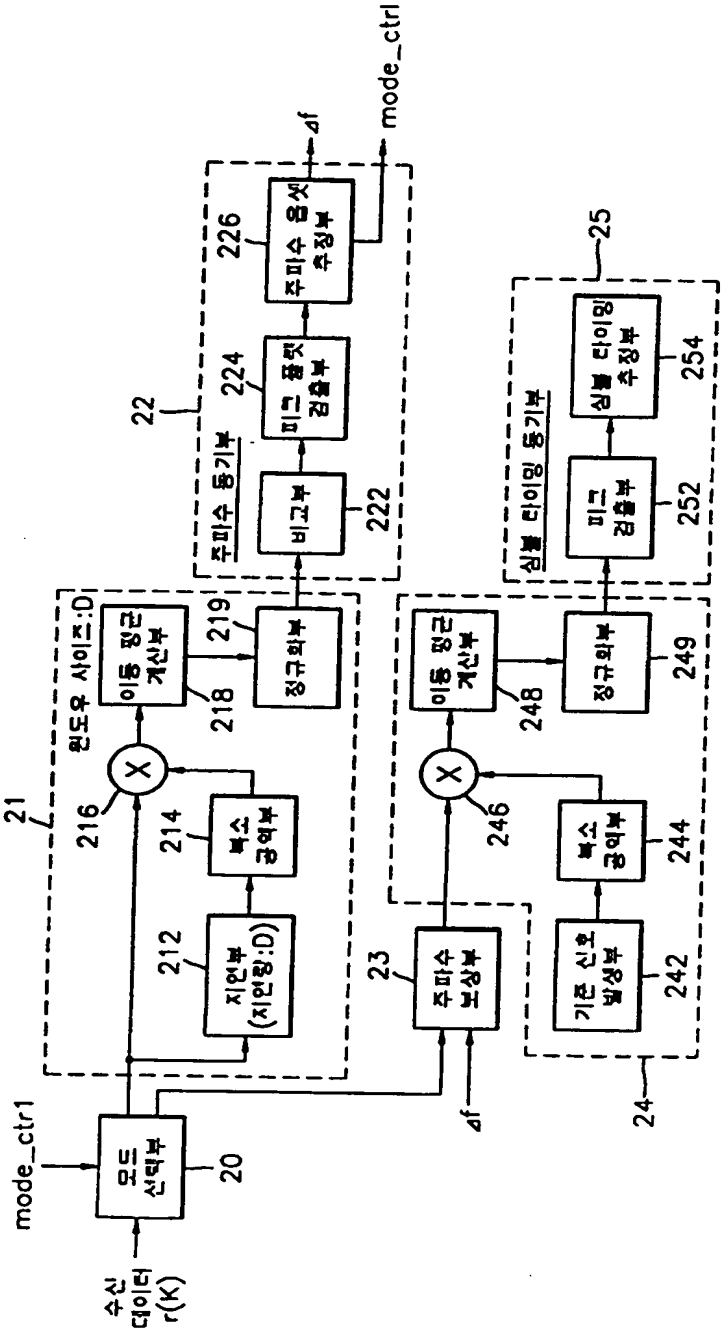
SYN_C
페이로드
자기 상관값
피크점—심볼타이밍 동기
—소수배 주파수 동기
FFT
정수배 주파수 동기

【도 2】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20
21
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지연부 (지연량:D)
212
복소 공액부
214
이동 평균 계산부
216
218
정규화부
219
비교부
222
주파수 동기부
22
피크 검출부
224
주파수 옵셋 추정부
226
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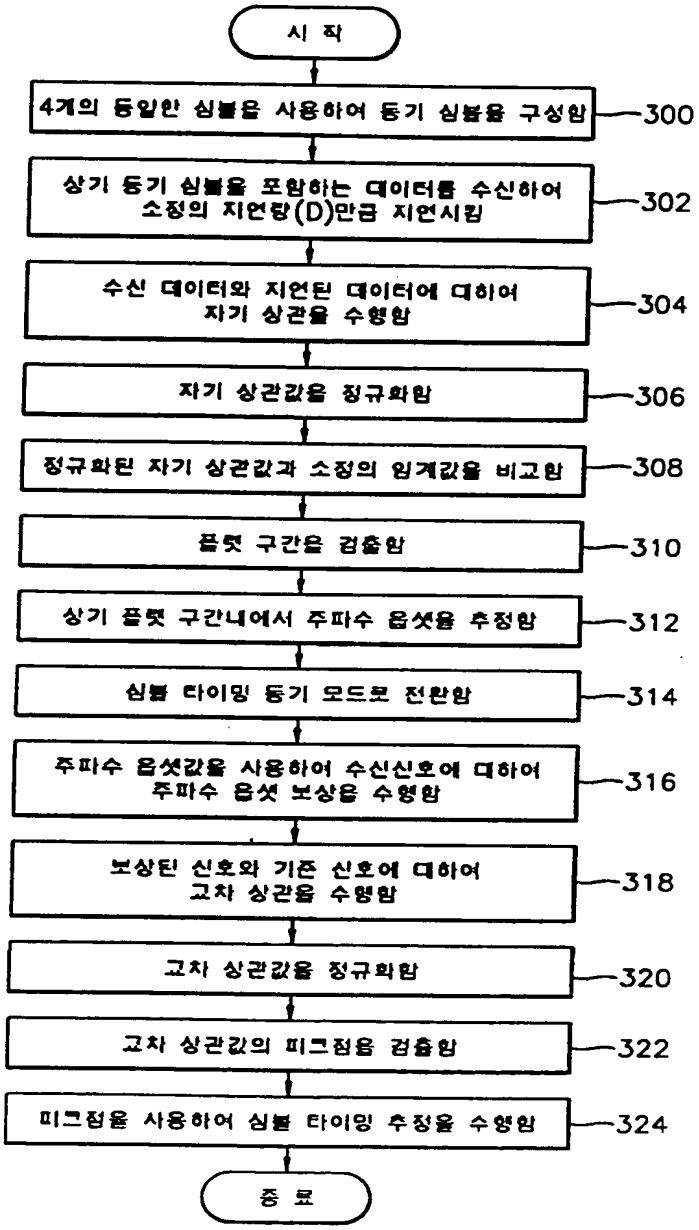
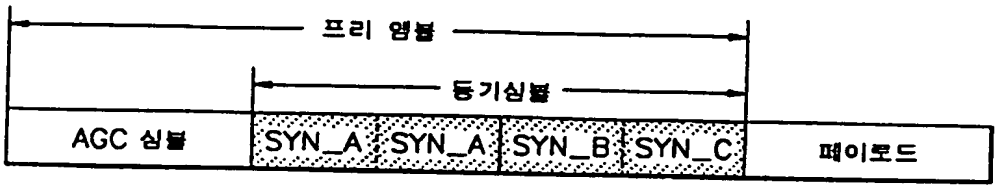
23
주파수 보상부
df
이동 평균 계산부
246
248
정규화부
249
24
기존 신호 발생부
242
복소 공액부
244
피크 검출부
252
심볼 타이밍 동기부
25
심볼 타이밍 추정부
254

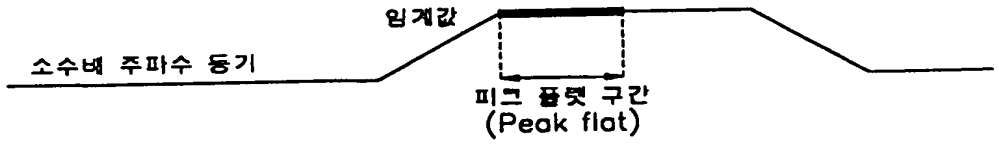
【도 3】


시 작
4개의 등일한 심볼을 사용하여 등기 심볼을 구성함
300
상기 등기 심볼을 포함하는 데이터를 수신하여 소정의 지연량(D)만큼 지연시킴
302
수신 데이터와 지연된 데이터에 대하여 자기 상관을 수행함
304
자기 상관값을 정규화함
306
정규화된 자기 상관값과 소정의 임계값을 비교함
308
플랫 구간을 검출함
310
상기 플랫 구간내에서 주파수 옵셋을 추정함
312
심볼 타이밍 등기 모드로 전환함
314
주파수 옵셋값을 사용하여 수신신호에 대하여 주파수 옵셋 보상을 수행함
316
보상된 신호와 기존 신호에 대하여 고차 상관을 수행함
318
고차 상관값을 정규화함
320
고차 상관값의 피크점을 검출함
322
피크점을 사용하여 심볼 타이밍 추정을 수행함
324
종 료

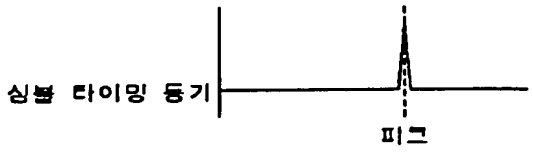
【도 4a】


프리 앰블
동기심볼
AGC 심볼
SYN_A
SYN_A
SYN_B
SYN_C
페이로드

【도 4b】


임계값
소수배 주파수 동기
피크 플랫 구간
(Peak flat)

【도 4c】


심볼 타이밍 동기
피크

PCT/KR00/00633
ISA/KR 18.08.2000

APPARATUS AND METHOD FOR ACHIEVING SYMBOL TIMING AND FREQUENCY SYNCHRONIZATION TO ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SIGNAL

Technical Field

The present invention relates to an apparatus and method for achieving symbol timing and frequency synchronization, and more particularly, to an apparatus and method for synchronizing symbol timing and frequency in an orthogonal frequency division multiplexing (OFDM) system. OFDM techniques have been adopted as a standard with respect to a physical layer in 802.11a of IEEE or HIPERLAN TYPE 2 of BRAN ETSI, which are the standards of a wideband wireless LAN. The present invention relates to a frequency synchronization apparatus and method which is suitable for this broad-band wireless LAN.

Background Art

A conventional OFDM timing and frequency synchronization method is disclosed in U.S. Patent No. 5,732,113, issued to Timothy M. Schmidl and Donald C. Cox, entitled "Timing and frequency synchronization of OFDM signals". FIGS. 1A is a block diagram of the structure of a conventional timing and frequency synchronization apparatus disclosed in the above-described patent, and FIG. 1B is a view for illustrating the operation of the apparatus of FIG. 1A.

Referring to FIGS. 1A and 1B, in a conventional timing and frequency synchronization apparatus, a synchronizing symbol having a length of a half symbol is made up of two symbols SYN_A, a symbol SYN_B and a symbol SYN_C. A maximum point is detected by autocorrelating between the synchronizing symbol formed as described above and a delayed symbol. A symbol timing is obtained from the detected maximum point, and decimal multiple frequency offset compensation is performed. Then, an inverse Fourier transformer inverse-Fourier-transforms a received time-domain signal

and the compensated received signal into a frequency domain signal. Also, integral-multiple frequency offset compensation is performed using a differential signal obtained by differentially encoding the synchronizing symbols A and B.

However, the above-described conventional method has a problem in that the probability of an error occurring during obtaining symbol timing is high since a variation in the maximum point of an autocorrelation value is great due to the influence of noise in a channel. Also, fine frequency synchronization and coarse frequency synchronization depend on symbol timing synchronization, so that they are sensitive to the influence of symbol timing errors. Furthermore, in the above-described conventional method, a received signal stored in a memory, and a current received signal are both inversely Fourier transformed, which causes complexity.

Meanwhile, a broad-band wireless LAN uses a 20 MHz frequency band and 64 sub-carriers, and a maximum frequency offset is set to be 200 kHz. Thus, a broad-band wireless LAN does not consider a frequency offset which corresponds to an integral multiple of a sub-carrier frequency. However, the conventional frequency and symbol synchronization method of OFDM signals considers an integral-multiple frequency offset, so that it is not efficient.

Disclosure of the Invention

An objective of the present invention is to provide a frequency and symbol timing synchronization apparatus which can acquire more accurate frequency synchronization and more accurate symbol timing synchronization from an orthogonal frequency division multiplexed (OFDM) signal which has passed through a multi-path channel to which noise is added and which causes distortion of amplitude and phase.

Another objective of the present invention is to provide a frequency and symbol timing synchronization method which is performed in the frequency and symbol timing synchronization apparatus.

The first objective of the present invention is achieved by a frequency

and symbol timing synchronization apparatus for achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the apparatus including an autocorrelation unit, a comparator, a peak flat detector, a frequency offset estimator, a frequency offset compensation unit, a cross correlation unit and a symbol timing synchronization unit. The autocorrelation unit receives data including a synchronizing symbol made up of at least three identical synchronizing signals, delays the received data by a predetermined delay amount, performs autocorrelation between the received data and the delayed data, normalizes an autocorrelated value, and outputs a normalized autocorrelated value. The comparator compares the normalized autocorrelated value with a predetermined threshold value. The peak flat detector detects as a flat section a section where the normalized autocorrelated value is equal to or greater than the threshold value. The frequency offset estimator estimates a frequency offset within the flat section to obtain a frequency offset value. The frequency offset compensation unit compensates for the frequency offset of a received signal using the frequency offset value. The cross correlation unit performs cross correlation using a frequency offset-compensated signal and a reference signal, and normalizes the cross-correlated value to output a normalized cross-correlated value. The symbol timing synchronization unit detects a point where the cross-correlated value is maximum, and performs symbol timing estimation, thereby performing symbol timing synchronization.

It is preferable that the frequency and symbol timing synchronization apparatus further includes a mode selection unit for concluding a frequency synchronization mode and selecting a symbol timing synchronization mode.

Also, preferably, the length of the synchronous signal is equal to or less than the length of an OFDM half-symbol.

It is also preferable that the peak flat detector calculates the difference or ratio of the autocorrelated value and the threshold value and detects as a flat section a section where the difference or ratio is equal to or greater than a predetermined value.

Alternatively, the peak flat detector can detect as a flat section a section of a predetermined sample length after a point where the autocorrelated value is greater than the threshold value.

Also, alternatively, the peak flat detector can include an addition unit for calculating the sum of a predetermined number of samples after a point where the auto-correlated value is greater than or equal to the threshold value; and a flat section detection unit for calculating the difference or ratio of the sum and the threshold value and detecting as a flat section a section where the difference or ratio is greater than or equal to a predetermined value.

The frequency offset estimator can include a frequency offset estimation unit for obtaining frequency offset values by estimating a frequency offset within the section two or more times; and an averaging unit for calculating the average of the obtained frequency offset values to obtain an average frequency offset value.

The second objective of the present invention is achieved by a frequency and symbol timing synchronization method for achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the method including: (a) organizing a synchronizing symbol with at least three identical synchronous signals; (b) receiving a signal including the synchronizing symbol, delaying the received signal by a predetermined delay amount, performing autocorrelation between the received signal and the delayed signal, normalizing an autocorrelated value, and detecting as a flat section a section where the normalized autocorrelated value is greater than a predetermined threshold value; (c) estimating a frequency offset within the flat section to obtain a frequency offset value; (d) compensating for the frequency offset of the received signal using the frequency offset value; (e) performing symbol timing synchronization using a frequency offset-compensated signal and a reference signal.

Brief Description of the Drawings

FIG. 1A is a block diagram of a conventional apparatus for achieving symbol timing and frequency synchronization of orthogonal frequency division multiplexed (OFDM) signals;

FIG. 1B is a view illustrating a symbol timing and frequency synchronization method which is performed in the symbol timing and frequency synchronization apparatus of FIG. 1A;

FIG. 2 is a block diagram of an apparatus for achieving symbol timing and frequency synchronization of OFDM signals according to an embodiment of the present invention;

FIG. 3 is a flowchart illustrating a method of achieving symbol timing and frequency synchronization of OFDM signals according to an embodiment of the present invention; and

FIGS. 4A, 4B and 4C are views for illustrating the operation of an apparatus for achieving symbol timing and frequency synchronization of OFDM signals according to an embodiment of the present invention.

Best mode for carrying out the Invention

Referring to FIG. 2, a method for achieving symbol timing and frequency synchronization to orthogonal frequency division multiplexed (OFDM) signals, according to an embodiment of the present invention, includes a mode selection unit 20, an autocorrelation unit 21, a frequency synchronization unit 22, a frequency offset compensation unit 23, a cross-correlation unit 24, and a symbol timing synchronization unit 25. The autocorrelation unit 21 includes a delay unit 212, a complex conjugator 214, a multiplier 216, a moving average calculator 218, and a normalizer 219. The frequency synchronization unit 22 includes a comparator 222, a peak flat detector 224, and a frequency offset estimator 226. The cross correlation unit 24 includes a reference signal generator 242, a complex conjugator 244, a multiplier 246, a moving average calculator 248, and a normalizer 249.

FIGS. 4A through 4C are views for illustrating the operation of an apparatus for achieving frequency and symbol timing synchronization of

OFDM signals according to the present invention, and a frequency and symbol timing synchronization method according to the present invention. This apparatus receives an OFDM signal. The OFDM signal is made up of preamble data and payload data. The preamble data include an AGC symbol and a synchronizing symbol. The synchronizing symbol used in this embodiment includes four identical symbols SYNC_A as shown in FIG. 4A. That is, in this embodiment, a synchronizing symbol is made up of four symbols each having a length of 32 samples, which is half the length, 64 samples, of an OFDM symbol, in step 300. It is assumed that an OFDM signal having this synchronizing symbol is received. Preferably, the length of the synchronizing symbol is half the length of an OFDM symbol.

The mode selection unit 20 first selects a frequency synchronization mode. The delay unit 212 delays received data r(K) by a predetermined delay amount (D) which corresponds to the length, 32 samples, of each symbol used during synchronization, in step 302. The complex conjugator 214 complex-conjugates delayed data r(K-D). The multiplier 216 multiplies the received data r(K) by the delayed data r(K-D), and the moving average calculator 218 calculates a moving average. Here, the size of a window for the moving average corresponds to the delay amount (D), that is, 32 samples. As described above, the multiplier 216 and the moving average calculator 218 perform autocorrelation, in step 304, and output an autocorrelated value. Next, the normalizer 219 normalizes the autocorrelated value, in step 306. Consequently, the autocorrelation unit 210 outputs a normalized autocorrelated value.

The comparator 222 compares the normalized autocorrelated value to a predetermined threshold value, in step 308. The peak flat detector 224 detects a section where the normalized autocorrelated value is equal to or greater than the threshold value, as a flat section as shown in FIG. 4B, in step 310. The peak flat detector 224 can detect as a flat section a section where the difference or ratio between the autocorrelated value and the threshold value is greater than a predetermined value. Alternatively, the peak flat

detector 224 can detect as the flat section a section having a predetermined sample length after a point where the auto-correlated value is greater than the threshold value. Also, alternatively, the peak flat detector 224 can be made up of an addition unit (not shown) and a flat section detection unit (not shown). The addition unit calculates the sum of a predetermined number of samples after a point where the autocorrelated value is greater than the threshold value. The flat section detection unit (not shown) detects a section where the difference or ratio between the sum and the threshold value is greater than a predetermined value.

The frequency offset estimator 226 estimates a frequency offset within the flat section to obtain a frequency offset value, in step 312. Here, frequency offset estimation can be performed at an arbitrary point within the flat section, so that it allows an error of about ±16 samples. The frequency offset estimator 226 also outputs a mode control signal **mode_ctrl** received by the mode selection unit 20, when estimation of a frequency offset value is completed. In this way, the frequency synchronization unit 22 obtains a frequency offset value by estimating a frequency offset within a flat section.

Alternatively, the frequency offset estimator 226 can be made up of a frequency offset calculation unit (not shown)m and an averaging unit (not shown). The frequency offset calculation unit calculates a plurality of frequency offset values within a flat section two or more times. The averaging unit obtains an averaged frequency offset value by calculating the average of the plurality of frequency offset values, and outputs the averaged frequency offset value as a final frequency offset value.

Following this, the mode selection unit 20 concludes the frequency synchronization mode in response to the mode control signal and selects a symbol timing synchronization mode.

The frequency offset compensation unit 23 performs frequency offset compensation on a received signal using the final frequency offset value obtained by the frequency synchronization unit 22.

The reference signal generator 242 generates and outputs a reference

signal, and the complex conjugator 244 complex-conjugates the reference signal. The multiplier 246 multiplies the complex-conjugated reference signal by the frequency offset-compensated signal output from the frequency compensator 23, and the moving average calculator 248 calculates a moving average. That is, a cross correlated value is obtained by cross correlation performed by the multiplier 246 and the moving average calculator 248. The normalizer 249 normalizes the cross correlated value output from the moving average calculator. In this way, the cross correlation unit 24 performs cross correlation using the frequency offset-compensated signal and the reference signal and normalizes a cross correlated value, thereby outputting a normalized cross correlated value.

The symbol timing synchronization unit 25 detects a point where the cross correlated value is maximum, as shown in FIG. 4C. At this time, an accurate maximum point can be estimated since a received signal has been frequency-compensated. Thus, symbol timing estimation is performed using the accurately-estimated maximum point, thereby reducing symbol timing errors.

As described above, in the symbol timing and frequency synchronization apparatus and method according to the present invention, frequency synchronization and symbol timing synchronization are sequentially performed, and an error of about ± 16 samples is allowed. That is, a large sample error can be allowed, so that accurate frequency synchronization can be achieved. Also, symbol timing estimation is performed using an accurately-estimated maximum point, thereby reducing a symbol timing error.

As described above, in the symbol timing and frequency synchronization apparatus and method according to the present invention, accurate frequency synchronization can be achieved because relatively large sample error can be allowed. Also, a symbol timing error can be reduced since symbol timing synchronization is achieved using a frequency offset-compensated signal.

Industrial Applicability

A symbol timing and frequency synchronization apparatus and method according to the present invention is suitable for a wideband wireless LAN which does not require a coarse frequency offset estimation, since a frequency offset that is smaller than a symbol spacing is defined.

What is claimed is:

1. A frequency and symbol timing synchronization apparatus for achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the apparatus comprising:

an autocorrelation unit for receiving data including a synchronizing symbol made up of at least three identical synchronizing signals, delaying the received data by a predetermined delay amount, performing autocorrelation between the received data and the delayed data, normalizing an autocorrelated value, and outputting a normalized autocorrelated value;

a comparator for comparing the normalized autocorrelated value with a predetermined threshold value;

a peak flat detector for detecting as a flat section a section where the normalized autocorrelated value is equal to or greater than the threshold value;

a frequency offset estimator for estimating a frequency offset within the flat section to obtain a frequency offset value;

a frequency offset compensation unit for compensating for the frequency offset of a received signal using the frequency offset value;

a cross correlation unit for performing cross correlation using a frequency offset-compensated signal and a reference signal, and normalizing the cross-correlated value to output a normalized cross-correlated value; and

a symbol timing synchronization unit for detecting a point where the cross-correlated value is maximum, and performing symbol timing estimation, thereby performing symbol timing synchronization.

2. The frequency and symbol timing synchronization apparatus of claim 1, further comprising a mode selection unit for concluding a frequency synchronization mode and selecting a symbol timing synchronization mode.

3. The frequency and symbol timing synchronization apparatus of

claim 1 or 2, wherein the length of the synchronous signal is equal to or less than the length of an OFDM half-symbol.

4. The frequency and symbol timing synchronization apparatus of claim 1, wherein the peak flat detector calculates the difference or ratio of the autocorrelated value and the threshold value and detects as a flat section a section where the difference or ratio is equal to or greater than a predetermined value.

5. The frequency and symbol timing synchronization apparatus of claim 1, wherein the peak flat detector detects as a flat section a section of a predetermined sample length after a point where the autocorrelated value is greater than the threshold value.

6. The frequency and symbol timing synchronization apparatus of claim 1, wherein the peak flat detector comprises:

an addition unit for calculating the sum of a predetermined number of samples after a point where the auto-correlated value is greater than or equal to the threshold value; and

a flat section detection unit for calculating the difference or ratio of the sum and the threshold value and detecting as a flat section a section where the difference or ratio is greater than or equal to a predetermined value.

7. The frequency and symbol timing synchronization apparatus of claim 1, wherein the frequency offset estimator comprises:

a frequency offset estimation unit for obtaining frequency offset values by estimating a frequency offset within the section two or more times; and

an averaging unit for calculating the average of the obtained frequency offset values to obtain an average frequency offset value.

8. A frequency and symbol timing synchronization method for

achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the method comprising:

(a) organizing a synchronizing symbol with at least three identical synchronous signals;

(b) receiving a signal including the synchronizing symbol, delaying the received signal by a predetermined delay amount, performing autocorrelation between the received signal and the delayed signal, normalizing an autocorrelated value, and detecting as a flat section a section where the normalized autocorrelated value is greater than a predetermined threshold value;

(c) estimating a frequency offset within the flat section to obtain a frequency offset value;

(d) compensating for the frequency offset of the received signal using the frequency offset value;

(e) performing symbol timing synchronization using a frequency offset-compensated signal and a reference signal.

9. The frequency and symbol timing synchronization method of claim 8, further comprising the step of concluding a frequency synchronization mode and selecting a symbol timing synchronization mode.

10. The frequency and symbol timing synchronization method of claim 8 or 9, wherein the length of the synchronous signal is equal to or less than the length of an OFDM half-symbol.

11. The frequency and symbol timing synchronization method of claim 8, wherein in the step (b), the difference or ratio of the autocorrelated value and the threshold value is calculated, and a section where the difference or ratio is equal to or greater than a predetermined value is detected as a flat section.

12. The frequency and symbol timing synchronization method of claim 8, wherein in the step (b), a section of a predetermined sample length after a point where the autocorrelated value is greater than the threshold value, is detected as a flat section.

13. The frequency and symbol timing synchronization method of claim 8, wherein the step (b) comprises:

calculating the sum of a predetermined number of samples after a point where the auto-correlated value is greater than or equal to the threshold value; and

calculating the difference or ratio of the sum and the threshold value and detecting as a flat section a section where the difference or ratio is greater than or equal to a predetermined value.

14. The frequency and symbol timing synchronization method of claim 8, wherein the step (c) comprises:

estimating a frequency offset within the flat section two or more times; and

calculating the average of the obtained frequency offset-estimated values to obtain an average frequency offset value.

Abstract of the Invention

A frequency and symbol timing synchronization apparatus for orthogonal frequency division multiplexed (OFDM) signals, and a method performed by the apparatus are provided. This apparatus includes an autocorrelation unit, a comparator, a peak flat detector, a frequency offset estimator, a frequency offset compensation unit, a cross correlation unit and a symbol timing synchronization unit. The autocorrelation unit receives data including a synchronizing symbol made up of at least three identical synchronizing signals, delays the received data by a predetermined delay amount, performs autocorrelation between the received data and the delayed data, normalizes an autocorrelated value, and outputs a normalized autocorrelated value. The comparator compares the normalized autocorrelated value with a predetermined threshold value. The peak flat detector detects as a flat section a section where the normalized autocorrelated value is equal to or greater than the threshold value. The frequency offset estimator estimates a frequency offset within the flat section to obtain a frequency offset value. The frequency offset compensation unit compensates for the frequency offset of a received signal using the frequency offset value. The cross correlation unit performs cross correlation using a frequency offset-compensated signal and a reference signal, and normalizes the cross-correlated value to output a normalized cross-correlated value. The symbol timing synchronization unit detects a point where the cross-correlated value is maximum, and performs symbol timing estimation, thereby performing symbol timing synchronization. In the symbol timing and frequency synchronization apparatus and method, accurate frequency synchronization can be achieved because a large sample error can be allowed. Also, a symbol timing error can be reduced since symbol timing synchronization is achieved using a frequency offset-compensated signal.

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FIG. 1A

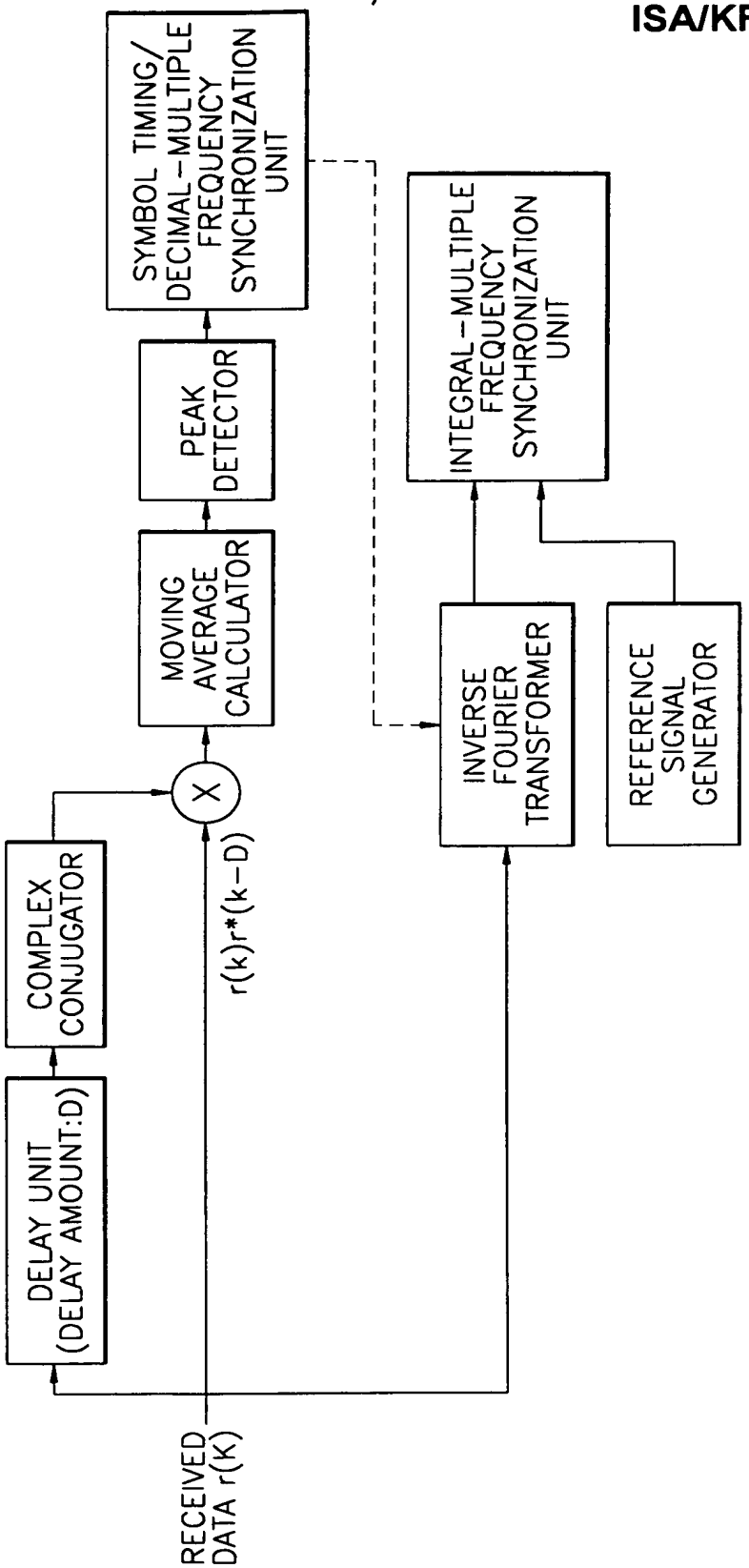

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FIG. 1B

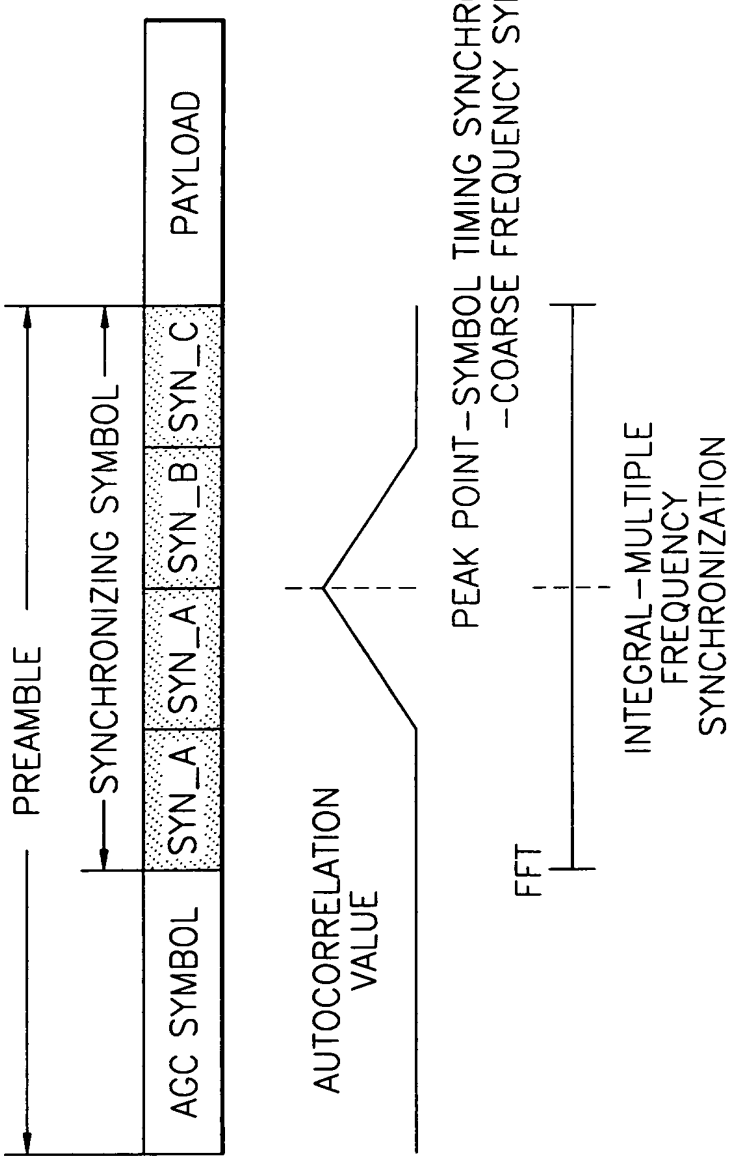

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FIG. 2

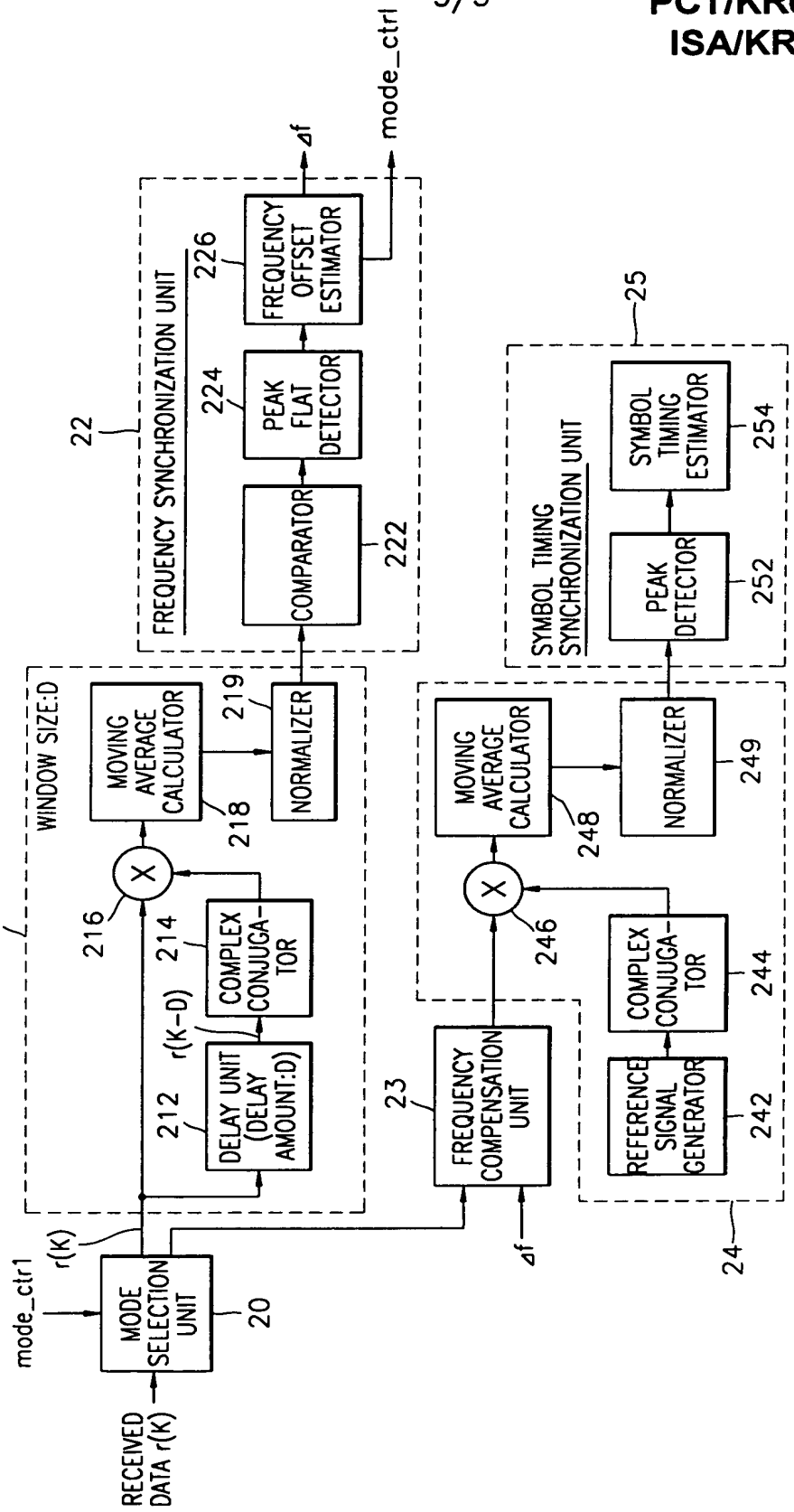

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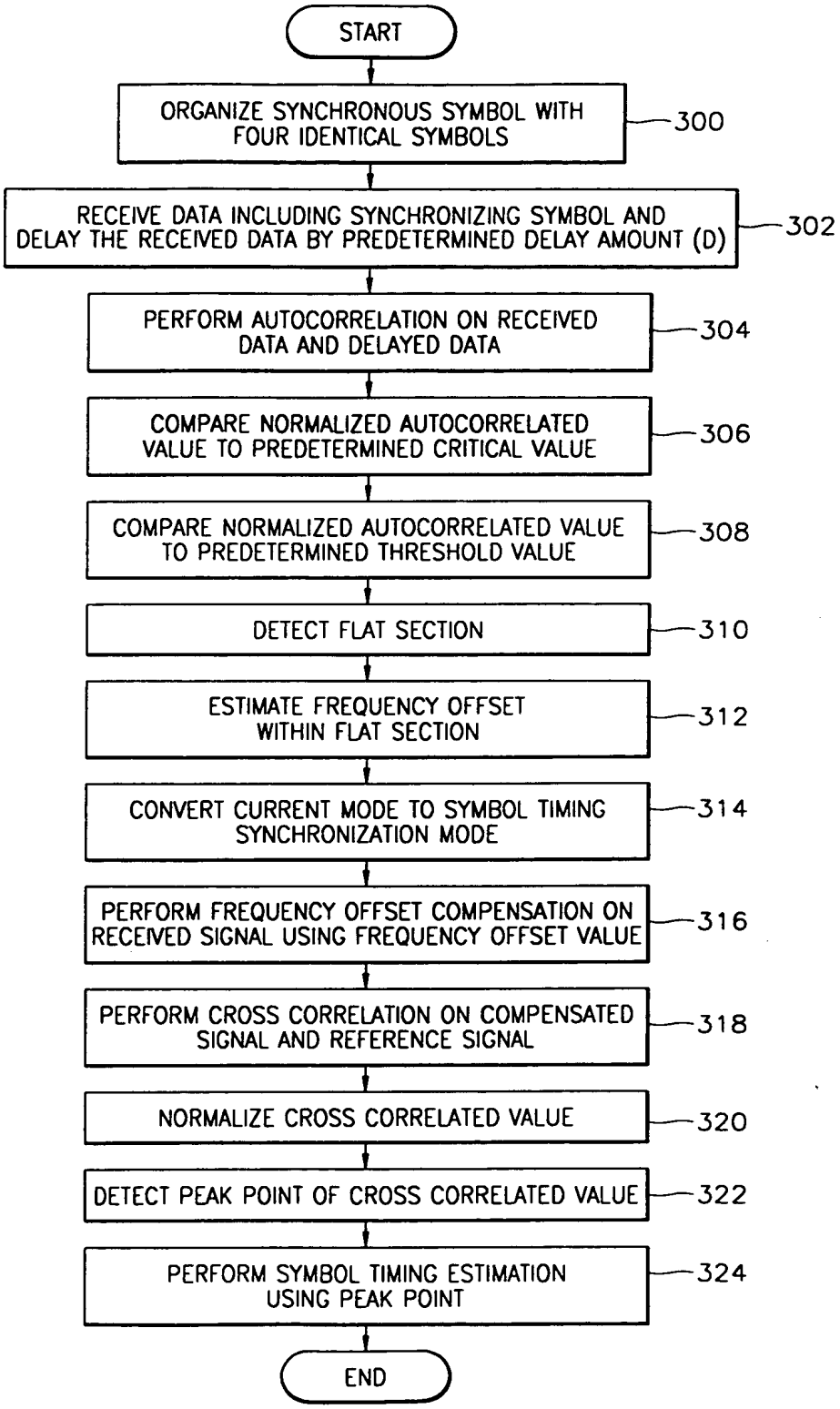
FIG. 3



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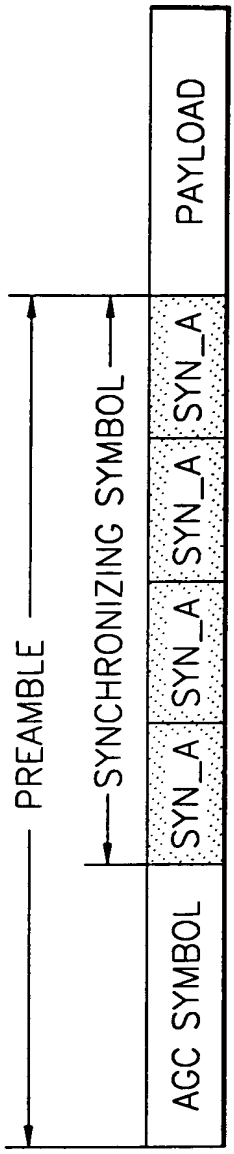

FIG. 4A

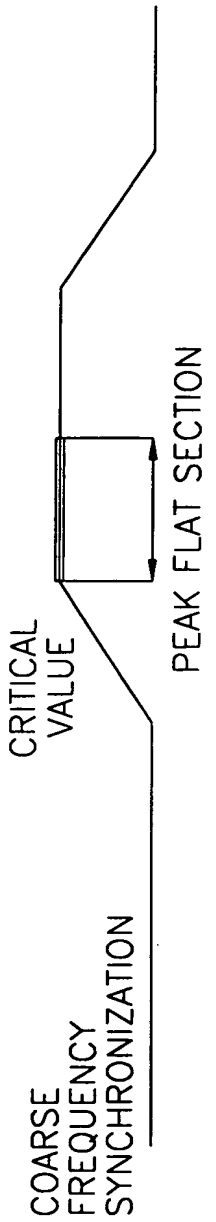

FIG. 4B

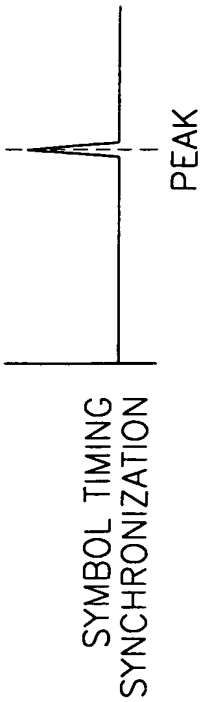

FIG. 4C

【명세서】

【발명의 명칭】

직교주파수분할다중변조 신호의 심볼 타이밍 및 주파수 동기 장치 및 방법

【기술분야】

본 발명은 심볼 타이밍 및 주파수 동기 장치 및 방법에 관한 것으로, 특히, 직교주파수분할다중변조 시스템의 심볼 타이밍 및 주파수 동기 장치 및 방법에 관한 것이다. 직교주파수분할다중변조 기술은 광대역 무선 LAN에 관한 표준인 IEEE의 802.11a나 BRAN ETSI의 HIPERLAN TYPE 2에서 물리계층에 대한 표준으로 채택되었다. 본 발명은 이러한 광대역 무선 LAN에 적합한 주파수 동기 장치 및 방법에 관한 것이다.

【배경기술】

종래의 OFDM 타이밍 및 주파수 동기 방법이 티모시 엠 쉬미디와 도널드 씨 콕스에 의한 "OFDM 신호의 타이밍 및 주파수 동기"라는 제목의 미국 특허 제 5,732,113호에 개시되어 있다. 도 1a와 도 1b에는 상기 특허 자료에 개시된 종래기술에 따른 타이밍 및 주파수 동기 장치의 구조를 설명하기 위한 블록도와 상기 장치의 동작을 설명하기 위한 도면을 각각 도시하였다.

도 1a 및 도 1b를 참조하면, 종래의 타이밍 및 주파수 동기 장치에서는 1/2 심볼 길이를 가지는 2 개의 심볼(A)과, 심볼(B), 및 심볼(C)로 구성된 동기 심볼을 구성한다. 이와같이 구성된 심볼과 지연된 심볼 사이의 자기상관을 적용하여 최대점을 검출한다. 이러한 최대점에서 심볼 타이밍을 획득하고, 소수배 주파수 옵셋 보상을 수행한다. 다음에는, 역푸리에변환부는 수신신호와 보상된 수신신호를 역푸리에 변환하여 주파수 영역으로 변환한다. 또한, 동기 심볼 A와 B를 차등 인코딩한 차등 신호를 사용하여 정수배 주파수 옵셋 보상을 수행한다.

하지만, 상기와 같은 종래의 방법은 잡음과 채널의 영향으로 자기상관값의 최대점의 변화도가 크기 때문에 심볼 타이밍을 획득하는데 있어서 오류 발생확률이 높다는 문제점이 있다. 또한, 소수배 및 정수배 주파수 동기는 심볼 타이밍 동기에 의존하기 때문에 심볼 타이밍 오류의 영향에 민감하다는 문제점이 있다. 더욱이, 상기와 같은 종래의 방법은 메모리에 저장된 수신신호와 현재 수신되는 신호를 모두 역푸리에변환하기 때문에 복잡성이 높다는 문제점이 있다.

한편, 광대역 무선 LAN은 20 ㎒의 주파수 대역과 64 개의 부반송파를 사용하고, 최대 주파수 옵셋은 200 ㎑로 규정하고 있다. 따라서, 광대역 무선

LAN에서는 부반송파 주파수의 정수배에 해당하는 주파수 옵셋은 고려하고 있지 않다. 하지만, 종래의 OFDM 신호에 대한 주파수 및 심볼 타이밍 동기 방법에서는 정수배의 주파수 옵셋을 규정하고 있기 때문에 효율적이지 못하다는 문제점이 있다.

【발명의 상세한 설명】

본 발명이 이루고자 하는 기술적인 과제는 잡음이 부가되고 진폭과 위상 왜곡을 야기시키는 다중 경로 채널을 통과한 OFDM 신호로부터 보다 정확하게 주파수 동기와 심볼 타이밍 동기를 획득할 수 있는 주파수 및 심볼 타이밍 동기 장치를 제공하는 것이다.

본 발명이 이루고자 하는 다른 기술적인 과제는 상기 주파수 및 심볼 타이밍 동기 장치내에서 수행되는 심볼 타이밍 및 주파수 동기 방법을 제공하는 것이다.

상기 과제를 이루기 위하여 본 발명에 따른 심볼 타이밍 및 주파수 동기 장치는 직교주파수분할다중화 신호로부터 주파수 동기와 심볼 타이밍 동기를 획득하기 위한 주파수 및 심볼 타이밍 동기 장치에 있어서, 적어도 세 개 이상의 동일한 동기 신호를 사용하여 구성된 동기 심볼을 포함하는 데이터를 수신하여 소정의 지연량 만큼 지연시켜 수신데이터와 자기 상관을 수행하고, 정규화를 수행하여 정규화된 자기 상관값을 출력하는 자기상관부; 정규화된 자기 상관값과 소정의 임계값을 비교하는 비교부; 정규화된 자기 상관값이 소정의 임계값 이상인 구간을 플랫 구간으로서 검출하는 피크 플랫 검출부; 상기 플랫 구간내에서 주파수 옵셋을 추정하여 주파수 옵셋값을 구하는 주파수 옵셋 추정부; 상기 주파수 옵셋값을 사용하여 수신신호에 대하여 주파수 옵셋 보상을 수행하는 주파수 옵셋 보상부; 주파수 옵셋이 보상된 신호와 기준신호를 사용하여 교차상관을 수행하고, 정규화를 수행하여 정규화된 교차 상관값을 출력하는 교차상관부; 및 상기 교차상관값이 최대가 되는 지점을 검출하고 심볼 타이밍 추정을 수행함으로써 심볼 타이밍 동기를 수행하는 심볼타이밍 동기부;를 포함하는 것을 특징으로 한다.

상기 장치는 주파수 동기를 수행하기 위한 주파수 동기모드를 종료하고 심볼 타이밍 동기를 수행하기 위한 심볼 타이밍 동기 모드로 절환시키는 모드 선택부를 더 포함하는 것이 바람직하다.

또한, 상기 동기 신호는 OFDM 심볼길이의 1/2 이하인 것이 바람직하다.

또한, 상기 피크 플랫 검출부는 자기상관값과 임계값의 차 또는 비를

구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 것이 바람직하다.

대안적으로, 상기 피크 플랫 검출부는 자기상관값이 임계값 이상이 되는 지점에서 소정의 샘플 길이에 해당하는 구간을 플랫 구간으로서 검출하여도 무방하더.

또한, 대안적으로, 상기 피크 플랫 검출부는 자기상관값이 임계값 이상이 되는 지점이후에 소정 개수의 샘플에 대한 합을 구하는 합산수단; 및 상기 합과 임계값의 차 또는 비를 구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 플랫구간 검출수단;을 포함하여 이루어질 수 있다.

또한, 상기 주파수 옵셋 추정부는 상기 구간내에서 주파수 옵셋 추정을 2회 이상 수행함으로써 주파수 옵셋값을 구하고 상기 주파수 옵셋값을 합산하는 주파수옵셋추정부; 및 상기 합산된 주파수 옵셋값을 평균하여 주파수 옵셋값을 구하는 평균화수단;을 포함하여 이루어질 수 있다.

상기 다른 과제를 이루기 위하여 본 발명에 따른 심볼 타이밍 및 주파수 동기 방법은 직교주파수분할다중화 신호로부터 주파수 동기와 심볼 타이밍 동기를 획득하기 위한 주파수 및 심볼 타이밍 동기 방법에 있어서, (a) 적어도 세 개 이상의 동일한 동기 신호를 사용하여 동기 심볼을 구성하는 단계; (b) 상기 동기 심볼을 포함하는 데이터를 소정의 지연량 만큼 지연시켜 수신데이터와 자기상관을 수행하고, 정규화를 수행하여 정규화된 자기 상관값이 소정의 임계값 이상이 되는 구간을 플랫 구간으로서 검출하는 단계; (c) 상기 구간내에서 주파수 옵셋을 추정하여 주파수 옵셋값을 구하는 단계; (d) 상기 주파수 옵셋값을 사용하여 수신신호에 대하여 주파수 옵셋 보상을 수행하는 단계; 및 (e) 주파수 옵셋이 보상된 신호와 기준신호를 사용하여 심볼 타이밍 동기를 수행하는 단계;를 포함하는 것을 특징으로 한다.

【도면의 간단한 설명】

도 1a는 종래의 직교주파수분할다중변조 신호의 심볼 타이밍 및 주파수 동기 장치를 도시한 블록도이다.

도 1b는 도 1의 심볼 타이밍 및 주파수 동기 장치에서 수행되는 심볼 타이밍 및 주파수 동기 방법을 설명하기 위한 도면이다.

도 2는 본 발명의 실시예에 따른 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치를 도시한 흐름도이다.

도 3은 본 발명의 실시예에 따른 직교주파수분할다중화 신호의 주파수 및

심볼 타이밍 동기 방법을 도시한 흐름도이다.

도 4a 내지 도 4c는 본 발명의 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치 및 방법의 동작을 설명하기 위한 도면이다.

【실시예】

이하 첨부된 도면들을 참조하여 본 발명의 바람직한 실시예들을 상세히 기술하기로 한다.

도 2에는 본 발명의 실시예에 따른 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치를 흐름도로써 도시하였으며, 도 3에는 상기 장치에서 수행되는 본 발명의 실시예에 따른 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법을 흐름도로써 도시하였다. 또한, 도 4a 내지 도 4c에는 본 발명의 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치 및 방법의 동작을 설명하기 위한 도면을 도시하였다. 도 3와 도 4a 내지 도 4c는 이하에서 수시로 참조된다.

도 2를 참조하면, 본 발명에 의한 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치는 모드 선택부(20), 자기상관부(21), 주파수 동기부(22), 주파수 옵셋 보상부(23), 교차상관부(24), 및 심볼타이밍 동기부(25)를 포함한다. 자기상관부(21)는 지연부(212), 복소공액부(214), 승산기(216), 이동평균계산부(218), 및 정규화부(219)를 포함한다. 주파수 동기부(22)는 비교부(222), 피크 플랫 검출부(224), 및 주파수 옵셋 추정부(226)를 구비한다. 교차상관부(24)는 기준신호 발생부(242), 복소공액부(244), 승산기(246), 이동평균계산부(248), 및 정규화부(249)를 포함한다.

도 4a 내지 도 4c에는 본 발명의 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치 및 방법의 동작을 설명하기 위한 도면을 도시하였다.

상기와 같은 장치는 직교주파수분할다중화 신호를 수신한다. OFDM 신호는 프리앰블과 페이로드로 이루어진다. 프리앰블은 AGC 심볼과 동기심볼을 포함한다. 본 실시예에서 사용되는 동기심볼은 도 4a에 도시된 바와 같이 네 개의 동일한 동기 신호(SYNC_A)를 사용하여 구성된 동기 심볼을 포함한다. 즉, 본 실시예에서는 OFDM 심볼길이인 63의 1/2인 32인 네 개의 심볼을 사용하여 동기 심볼을 구성(단계 300)하고, 이러한 동기심볼을 포함하는 OFDM 신호가 입력되는 것으로 가정한다. 동기 심볼의 길이는 OFDM 심볼 길이의 1/2이하인 것이 바람직하다.

모드 선택부(20)는 초기에 주파수 동기를 수행하기 위한 주파수

동기모드를 선택한다. 지연부(212)는 수신된 데이터R(k)를 동기에 사용된 각 심볼의 길이인 32에 해당하는 소정의 지연량(D) 만큼 지연(단계 302)시킨다. 복소공액부(214)는 지연된 데이터R(k-D)를 복소공액화한다. 승산기(216)는 수신 데이터R(k)와 지연된 데이터R(k-D)를 곱하고, 이동평균계산부(218)에서는 이동 평균을 계산한다. 여기서, 이동 평균를 위한 창 크기는 지연량 D, 즉, 32에 해당한다. 이와같이, 승산기(216) 및 이동평균계산부(218)는 자기상관을 수행(단계 304)하며, 자기상관값을 출력한다. 다음으로, 정규화부(219)는 자기상관값을 정규화한다(단계 306). 결과적으로, 자기상관부(21)에서는 정규화된 자기상관값이 출력된다.

비교부(222)는 정규화된 자기 상관값과 소정의 임계값을 비교한다(단계 308). 피크 플랫 검출부(224)는 도 4b에 도시된 바와 같이 정규화된 자기 상관값이 소정의 임계값 이상인 구간을 플랫구간으로서 검출(단계 310)한다. 피크 플랫 검출부(224)는 자기상관값과 임계값의 차 또는 비를 구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 것이 가능하다. 대안적으로, 피크 플랫 검출부(224)는 자기상관값이 임계값 이상이 되는 지점에서 소정의 샘플 길이에 해당하는 구간을 플랫 구간으로서 검출하는 것도 가능하다. 또한, 대안적으로, 피크 플랫 검출부(224)는 자기상관값이 임계값 이상이 되는 지점이후에 소정 개수의 샘플에 대한 합을 구하는 합산수단(미도시)과 상기 합과 임계값의 차 또는 비를 구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 플랫구간 검출수단(미도시)를 구비하여 이루어질 수도 있다.

이제, 주파수 옵셋 추정부(226)는 상기 플랫 구간내에서 주파수 옵셋을 추정하여 주파수 옵셋값을 구한다(단계 312). 이때, 주파수 옵셋 추정은 상기 플랫 구간내의 임의의 지점에서 수행하는 것이 가능하므로, 약 ±16 샘플 정도의 오차를 허용한다. 주파수 옵셋 추정부(226)는, 또한, 주파수 옵셋값의 추정이 완료되면, 모드선택부(20)로 입력되는 모드제어신호를 출력한다. 이로써, 주파수 동기부(22)는 플랫 구간내에서 주파수 옵셋을 추정하여 주파수 옵셋값을 구한다.

대안적으로, 주파수 옵셋 추정부(226)는 플랫 구간내에서 주파수 옵셋 추정을 2 회 이상 수행함으로써 주파수 옵셋값을 구하고 상기 주파수 옵셋값을 합산하는 주파수옵셋추정부(미도시), 및 상기 합산된 주파수 옵셋값을 평균하여 주파수 옵셋값을 구하는 평균화수단(미도시)를 구비하여 이루어질 수도 있다.

다음으로, 모드 선택부(20)는 모드제어신호에 응답하여 주파수 동기모드를 종료하고 심볼 타이밍 동기를 수행하기 위한 심볼 타이밍 동기 모드로

절환시킨다.

주파수 옵셋 보상부(23)는 주파수 동기부(22)에 의하여 구해진 상기 주파수 옵셋값을 사용하여 수신신호에 대하여 주파수 옵셋 보상을 수행한다.

기준신호 발생부(242)는 기준신호를 출력하고, 복소공액부(244)는 상기 기준신호를 복소공액화한다. 승산기(246)는 복소공액화된 기준신호와 주파수 옵셋이 보상된 신호를 곱하고, 이동평균 계산부(248)에서는 이동평균을 계산한다. 즉, 승산기(246)와 이동평균계산부(248)에 의하여 교차상관이 수행됨으로써 교차상관값이 구해진다. 정규화부(249)는 교차상관값을 정규화한다. 이로써, 교차상관부(24)는 주파수 옵셋이 보상된 신호와 기준신호를 사용하여 교차상관을 수행하고 정규화를 수행함으로써 정규화된 교차 상관값을 출력한다.

심볼타이밍 동기부(25)는 도 4c에 도시된 바와 같이 상기 교차상관값이 최대가 되는 지점을 검출한다. 이때, 수신된 신호가 주파수 옵셋이 보상되어 있기 때문에 최대점을 정확하게 추정할 수 있다. 따라서, 정확하게 추정된 최대점을 사용하여 심볼 타이밍 추정을 수행함으로써 심볼 타이밍 오류를 줄일 수 있다.

이상에서와 같이 본 발명에 의한 심볼 타이밍 및 주파수 동기 장치 및 방법은 주파수 동기와 심볼 타이밍 동기를 순차적으로 수행하고, 약 ±16 샘플 정도의 오차를 허용하는 것과 같이 허용할 수 있는 샘플 오차가 크기 때문에 정확한 주파수 동기가 가능하다. 또한, 정확하게 추정된 최대점을 사용하여 심볼 타이밍 추정을 수행함으로써 심볼 타이밍 오류를 줄일 수 있다.

상술한 바와 같이 본 발명에 의한 심볼 타이밍 및 주파수 동기 장치 및 방법은 허용할 수 있는 샘플 오차가 크기 때문에 정확한 주파수 동기가 가능하고, 주파수 옵셋이 보상된 신호를 사용하여 심볼 타이밍 동기를 획득하기 때문에 심볼 타이밍 오류를 줄일 수 있다.

【산업상이용가능성】

본 발명에 의한 심볼 타이밍 및 주파수 동기 장치 및 방법은 심볼 간격보다 작은 주파수 옵셋을 규정하여 정수배의 주파수 옵셋이 필요하지 않은 광대역 무선 LAN에 적합하다.

【청구의 범위】

【청구항 1】

직교주파수분할다중화 신호로부터 주파수 동기와 심볼 타이밍 동기를 획득하기 위한 주파수 및 심볼 타이밍 동기 장치에 있어서,

적어도 세 개 이상의 동일한 동기 신호를 사용하여 구성된 동기 심볼을 포함하는 데이터를 수신하여 소정의 지연량 만큼 지연시켜 수신데이터와 자기 상관을 수행하고, 정규화를 수행하여 정규화된 자기 상관값을 출력하는 자기상관부;

정규화된 자기 상관값과 소정의 임계값을 비교하는 비교부;

정규화된 자기 상관값이 소정의 임계값 이상인 구간을 플랫 구간으로서 검출하는 피크 플랫 검출부;

상기 플랫 구간내에서 주파수 옵셋을 추정하여 주파수 옵셋값을 구하는 주파수 옵셋 추정부;

상기 주파수 옵셋값을 사용하여 수신신호에 대하여 주파수 옵셋 보상을 수행하는 주파수 옵셋 보상부;

주파수 옵셋이 보상된 신호와 기준신호를 사용하여 교차상관을 수행하고, 정규화를 수행하여 정규화된 교차 상관값을 출력하는 교차상관부; 및

상기 교차상관값이 최대가 되는 지점을 검출하고 심볼 타이밍 추정을 수행함으로써 심볼 타이밍 동기를 수행하는 심볼타이밍 동기부;를 포함하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치.

【청구항 2】

제1항에 있어서,

주파수 동기를 수행하기 위한 주파수 동기모드를 종료하고 심볼 타이밍 동기를 수행하기 위한 심볼 타이밍 동기 모드로 절환시키는 모드 선택부;를 더 포함하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치.

【청구항 3】

제1항 또는 제2항에 있어서, 상기 동기 신호는,

OFDM 1/2 심볼 길이 이하인것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치.

【청구항 4】

제1항에 있어서, 상기 피크 플랫 검출부는,

자기상관값과 임계값의 차 또는 비를 구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치.

〖청구항 5〗

제1항에 있어서, 상기 피크 플랫 검출부는,

자기상관값이 임계값 이상이 되는 지점에서 소정의 샘플 길이에 해당하는 구간을 플랫 구간으로서 검출하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치.

〖청구항 6〗

제1항에 있어서, 상기 피크 플랫 검출부는,

자기상관값이 임계값 이상이 되는 지점이후에 소정 개수의 샘플에 대한 합을 구하는 합산수단; 및

상기 합과 임계값의 차 또는 비를 구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 플랫구간 검출수단;을 포함하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치.

〖청구항 7〗

제1항에 있어서, 상기 주파수 옵셋 추정부는,

상기 구간내에서 주파수 옵셋 추정을 2 회 이상 수행함으로써 주파수 옵셋값을 구하고 상기 주파수 옵셋값을 합산하는 주파수옵셋추정부; 및

상기 합산된 주파수 옵셋값을 평균하여 주파수 옵셋값을 구하는 평균화수단;을 포함하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치.

〖청구항 8〗

직교주파수분할다중화 신호로부터 주파수 동기와 심볼 타이밍 동기를 획득하기 위한 주파수 및 심볼 타이밍 동기 방법에 있어서,

(a) 적어도 세 개 이상의 동일한 동기 신호를 사용하여 동기 심볼을 구성하는 단계;

(b) 상기 동기 심볼을 포함하는 데이터를 소정의 지연량 만큼 지연시켜 수신데이터와 자기 상관을 수행하고, 정규화를 수행하여 정규화된 자기 상관값이 소정의 임계값 이상이 되는 구간을 플랫 구간으로서 검출하는 단계;

(c) 상기 구간내에서 주파수 옵셋을 추정하여 주파수 옵셋값을 구하는 단계;

(d) 상기 주파수 옵셋값을 사용하여 수신신호에 대하여 주파수 옵셋 보상을 수행하는 단계; 및

(e) 주파수 옵셋이 보상된 신호와 기준신호를 사용하여 심볼 타이밍 동기를 수행하는 단계;를 포함하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법.

【청구항 9】

제8항에 있어서, 상기 (d) 단계 이전에,

주파수 동기를 수행하기 위한 주파수 동기모드를 종료하고 심볼 타이밍 동기를 수행하기 위한 심볼 타이밍 동기 모드로 절환시키는 단계를 더 포함하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법.

【청구항 10】

제8항 또는 제9항에 있어서, 상기 동기 신호는,

OFDM 심볼길이의 1/2 이하인 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법.

【청구항 11】

제8항에 있어서, 상기 (b) 단계는,

자기상관값과 임계값의 차 또는 비를 구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 단계인 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법.

【청구항 12】

제8항에 있어서, 상기 (b) 단계는,

자기상관값이 임계값 이상이 되는 지점에서 소정의 샘플 길이에 해당하는 구간을 플랫 구간으로서 검출하는 단계인 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법.

【청구항 13】

제8항에 있어서, 상기 (b) 단계는,

자기상관값이 임계값 이상이 되는 지점이후에 소정 개수의 샘플에 대한 합을 구하는 단계; 및

상기 합과 임계값의 차 또는 비를 구하여 그 값이 소정값 이상인 구간을 플랫 구간으로서 검출하는 단계인 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법.

【청구항 14】

제8항에 있어서, 상기 (c) 단계는,

상기 구간내에서 주파수 옵셋 추정을 2 회 이상 수행하는 단계; 및

구해진 주파수 옵셋 추정값을 평균하여 주파수 옵셋값을 구하는 단계;를 포함하는 것을 특징으로 하는 직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 방법.

【요약서】

【요약】

직교주파수분할다중화 신호의 주파수 및 심볼 타이밍 동기 장치 및 방법이 개시된다. 본 주파수 및 심볼 타이밍 동기 장치는 적어도 세 개 이상의 동일한 동기 신호를 사용하여 구성된 동기 심볼을 포함하는 데이터를 수신하여 소정의 지연량 만큼 지연시켜 수신데이터와 자기 상관을 수행하고, 정규화를 수행하여 정규화된 자기 상관값을 출력하는 자기상관부와, 정규화된 자기 상관값과 소정의 임계값을 비교하는 비교부와, 정규화된 자기 상관값이 소정의 임계값 이상인 구간을 플랫 구간으로서 검출하는 피크 플랫 검출부와, 상기 플랫 구간내에서 주파수 옵셋을 추정하여 주파수 옵셋값을 구하는 주파수 옵셋 추정부와, 상기 주파수 옵셋값을 사용하여 수신신호에 대하여 주파수 옵셋 보상을 수행하는 주파수 옵셋 보상부와, 주파수 옵셋이 보상된 신호와 기준신호를 사용하여 교차상관을 수행하고, 정규화를 수행하여 정규화된 교차 상관값을 출력하는 교차상관부, 및 상기 교차상관값이 최대가 되는 지점을 검출하고 심볼 타이밍 추정을 수행함으로써 심볼 타이밍 동기를 수행하는 심볼타이밍 동기부를 포함한다. 본 발명에 의한 심볼 타이밍 및 주파수 동기 방법은 허용할 수 있는 샘플 오차가 크기 때문에 정확한 주파수 동기가 가능하고, 주파수 옵셋이 보상된 신호를 사용하여 심볼 타이밍 동기를 획득하기 때문에 심볼 타이밍 오류를 줄일 수 있다.

【대표도】

도 2

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 December 2000 (21.12.2000)

PCT

(10) International Publication Number
WO 00/77961 A1

(51) International Patent Classification[7]: H04J 11/00, H04L 7/00

(21) International Application Number: PCT/KR00/00633

(22) International Filing Date: 15 June 2000 (15.06.2000)

(25) Filing Language: Korean

(26) Publication Language: English

(30) Priority Data:
1999/22297 15 June 1999 (15.06.1999) KR

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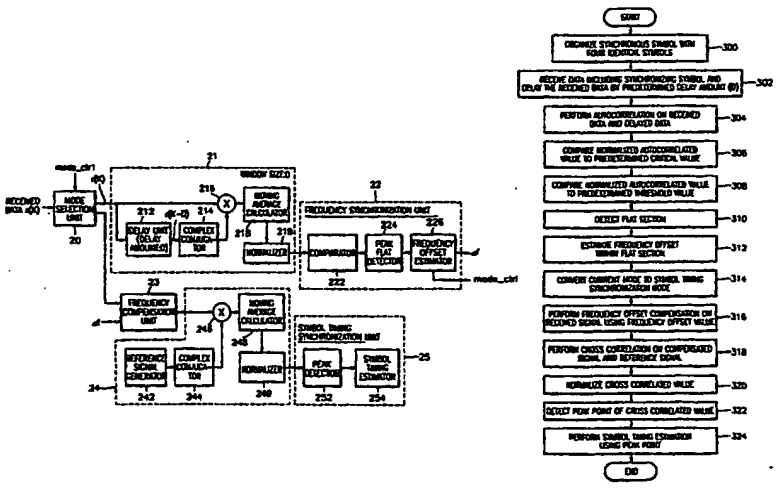
(81) Designated States *(national)*: CN, JP, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS AND METHOD FOR ACHIEVING SYMBOL TIMING AND FREQUENCY SYNCHRONIZATION TO ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SIGNAL



(57) Abstract: A frequency and symbol timing synchronization apparatus for orthogonal frequency division multiplexed (OFDM) signals, and a method performed by the apparatus are provided. This apparatus includes an autocorrelation unit, a comparator, a peak flat detector, a frequency offset estimator, a frequency offset compensation unit, a cross correlation unit and a symbol timing synchronization unit. The autocorrelation unit receives data including a synchronizing symbol made up of at least three identical synchronizing signals, delays the received data by a predetermined delay amount, performs autocorrelation between the received data and the delayed data, normalizes an autocorrelated value, and outputs a normalized autocorrelated value. The comparator compares the normalized autocorrelated value with a predetermined threshold value. The peak flat detector detects as a flat section a section where the normalized autocorrelated value is equal to or greater than the threshold value. The frequency offset estimator estimates a frequency offset within the flat section to obtain a frequency offset value. The frequency offset compensation unit compensates for the frequency offset of a received signal using the frequency offset value. The cross correlation unit performs cross correlation using a frequency offset-compensated signal and a reference signal, and normalizes the cross-correlated value to output a normalized cross-correlated value. The symbol timing synchronization unit detects a point where the cross-correlated value is maximum, and performs symbol timing estimation, thereby performing symbol timing synchronization. In the symbol timing and frequency synchronization apparatus and method, accurate frequency synchronization can be achieved because a large sample error can be allowed. Also, a symbol timing error can be reduced since symbol timing synchronization is achieved using a frequency offset-compensated signal.

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APPARATUS AND METHOD FOR ACHIEVING SYMBOL TIMING AND FREQUENCY SYNCHRONIZATION TO ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SIGNAL

Technical Field

The present invention relates to an apparatus and method for achieving symbol timing and frequency synchronization, and more particularly, to an apparatus and method for synchronizing symbol timing and frequency in an orthogonal frequency division multiplexing (OFDM) system. OFDM techniques have been adopted as a standard with respect to a physical layer in 802.11a of IEEE or HIPERLAN TYPE 2 of BRAN ETSI, which are the standards of a wideband wireless LAN. The present invention relates to a frequency synchronization apparatus and method which is suitable for this broad-band wireless LAN.

Background Art

A conventional OFDM timing and frequency synchronization method is disclosed in U.S. Patent No. 5,732,113, issued to Timothy M. Schmidl and Donald C. Cox, entitled "Timing and frequency synchronization of OFDM signals". FIGS. 1A is a block diagram of the structure of a conventional timing and frequency synchronization apparatus disclosed in the above-described patent, and FIG. 1B is a view for illustrating the operation of the apparatus of FIG. 1A.

Referring to FIGS. 1A and 1B, in a conventional timing and frequency synchronization apparatus, a synchronizing symbol having a length of a half symbol is made up of two symbols SYN_A, a symbol SYN_B and a symbol SYN_C. A maximum point is detected by autocorrelating between the synchronizing symbol formed as described above and a delayed symbol. A symbol timing is obtained from the detected maximum point, and decimal multiple frequency offset compensation is performed. Then, an inverse Fourier transformer inverse-Fourier-transforms a received time-domain signal

and the compensated received signal into a frequency domain signal. Also, integral-multiple frequency offset compensation is performed using a differential signal obtained by differentially encoding the synchronizing symbols A and B.

However, the above-described conventional method has a problem in that the probability of an error occurring during obtaining symbol timing is high since a variation in the maximum point of an autocorrelation value is great due to the influence of noise in a channel. Also, fine frequency synchronization and coarse frequency synchronization depend on symbol timing synchronization, so that they are sensitive to the influence of symbol timing errors. Furthermore, in the above-described conventional method, a received signal stored in a memory, and a current received signal are both inversely Fourier transformed, which causes complexity.

Meanwhile, a broad-band wireless LAN uses a 20 MHz frequency band and 64 sub-carriers, and a maximum frequency offset is set to be 200 kHz. Thus, a broad-band wireless LAN does not consider a frequency offset which corresponds to an integral multiple of a sub-carrier frequency. However, the conventional frequency and symbol synchronization method of OFDM signals considers an integral-multiple frequency offset, so that it is not efficient.

Disclosure of the Invention

An objective of the present invention is to provide a frequency and symbol timing synchronization apparatus which can acquire more accurate frequency synchronization and more accurate symbol timing synchronization from an orthogonal frequency division multiplexed (OFDM) signal which has passed through a multi-path channel to which noise is added and which causes distortion of amplitude and phase.

Another objective of the present invention is to provide a frequency and symbol timing synchronization method which is performed in the frequency and symbol timing synchronization apparatus.

The first objective of the present invention is achieved by a frequency

and symbol timing synchronization apparatus for achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the apparatus including an autocorrelation unit, a comparator, a peak flat detector, a frequency offset estimator, a frequency offset compensation unit, a cross correlation unit and a symbol timing synchronization unit. The autocorrelation unit receives data including a synchronizing symbol made up of at least three identical synchronizing signals, delays the received data by a predetermined delay amount, performs autocorrelation between the received data and the delayed data, normalizes an autocorrelated value, and outputs a normalized autocorrelated value. The comparator compares the normalized autocorrelated value with a predetermined threshold value. The peak flat detector detects as a flat section a section where the normalized autocorrelated value is equal to or greater than the threshold value. The frequency offset estimator estimates a frequency offset within the flat section to obtain a frequency offset value. The frequency offset compensation unit compensates for the frequency offset of a received signal using the frequency offset value. The cross correlation unit performs cross correlation using a frequency offset-compensated signal and a reference signal, and normalizes the cross-correlated value to output a normalized cross-correlated value. The symbol timing synchronization unit detects a point where the cross-correlated value is maximum, and performs symbol timing estimation, thereby performing symbol timing synchronization.

It is preferable that the frequency and symbol timing synchronization apparatus further includes a mode selection unit for concluding a frequency synchronization mode and selecting a symbol timing synchronization mode.

Also, preferably, the length of the synchronous signal is equal to or less than the length of an OFDM half-symbol.

It is also preferable that the peak flat detector calculates the difference or ratio of the autocorrelated value and the threshold value and detects as a flat section a section where the difference or ratio is equal to or greater than a predetermined value.

Alternatively, the peak flat detector can detect as a flat section a section of a predetermined sample length after a point where the autocorrelated value is greater than the threshold value.

Also, alternatively, the peak flat detector can include an addition unit for calculating the sum of a predetermined number of samples after a point where the auto-correlated value is greater than or equal to the threshold value; and a flat section detection unit for calculating the difference or ratio of the sum and the threshold value and detecting as a flat section a section where the difference or ratio is greater than or equal to a predetermined value.

The frequency offset estimator can include a frequency offset estimation unit for obtaining frequency offset values by estimating a frequency offset within the section two or more times; and an averaging unit for calculating the average of the obtained frequency offset values to obtain an average frequency offset value.

The second objective of the present invention is achieved by a frequency and symbol timing synchronization method for achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the method including: (a) organizing a synchronizing symbol with at least three identical synchronous signals; (b) receiving a signal including the synchronizing symbol, delaying the received signal by a predetermined delay amount, performing autocorrelation between the received signal and the delayed signal, normalizing an autocorrelated value, and detecting as a flat section a section where the normalized autocorrelated value is greater than a predetermined threshold value; (c) estimating a frequency offset within the flat section to obtain a frequency offset value; (d) compensating for the frequency offset of the received signal using the frequency offset value; (e) performing symbol timing synchronization using a frequency offset-compensated signal and a reference signal.

Brief Description of the Drawings

FIG. 1A is a block diagram of a conventional apparatus for achieving symbol timing and frequency synchronization of orthogonal frequency division multiplexed (OFDM) signals;

FIG. 1B is a view illustrating a symbol timing and frequency synchronization method which is performed in the symbol timing and frequency synchronization apparatus of FIG. 1A;

FIG. 2 is a block diagram of an apparatus for achieving symbol timing and frequency synchronization of OFDM signals according to an embodiment of the present invention;

FIG. 3 is a flowchart illustrating a method of achieving symbol timing and frequency synchronization of OFDM signals according to an embodiment of the present invention; and

FIGS. 4A, 4B and 4C are views for illustrating the operation of an apparatus for achieving symbol timing and frequency synchronization of OFDM signals according to an embodiment of the present invention.

Best mode for carrying out the Invention

Referring to FIG. 2, a method for achieving symbol timing and frequency synchronization to orthogonal frequency division multiplexed (OFDM) signals, according to an embodiment of the present invention, includes a mode selection unit 20, an autocorrelation unit 21, a frequency synchronization unit 22, a frequency offset compensation unit 23, a cross-correlation unit 24, and a symbol timing synchronization unit 25. The autocorrelation unit 21 includes a delay unit 212, a complex conjugator 214, a multiplier 216, a moving average calculator 218, and a normalizer 219. The frequency synchronization unit 22 includes a comparator 222, a peak flat detector 224, and a frequency offset estimator 226. The cross correlation unit 24 includes a reference signal generator 242, a complex conjugator 244, a multiplier 246, a moving average calculator 248, and a normalizer 249.

FIGS. 4A through 4C are views for illustrating the operation of an apparatus for achieving frequency and symbol timing synchronization of

OFDM signals according to the present invention, and a frequency and symbol timing synchronization method according to the present invention. This apparatus receives an OFDM signal. The OFDM signal is made up of preamble data and payload data. The preamble data include an AGC symbol and a synchronizing symbol. The synchronizing symbol used in this embodiment includes four identical symbols SYNC_A as shown in FIG. 4A. That is, in this embodiment, a synchronizing symbol is made up of four symbols each having a length of 32 samples, which is half the length, 64 samples, of an OFDM symbol, in step 300. It is assumed that an OFDM signal having this synchronizing symbol is received. Preferably, the length of the synchronizing symbol is half the length of an OFDM symbol.

The mode selection unit 20 first selects a frequency synchronization mode. The delay unit 212 delays received data r(K) by a predetermined delay amount (D) which corresponds to the length, 32 samples, of each symbol used during synchronization, in step 302. The complex conjugator 214 complex-conjugates delayed data r(K-D). The multiplier 216 multiplies the received data r(K) by the delayed data r(K-D), and the moving average calculator 218 calculates a moving average. Here, the size of a window for the moving average corresponds to the delay amount (D), that is, 32 samples. As described above, the multiplier 216 and the moving average calculator 218 perform autocorrelation, in step 304, and output an autocorrelated value. Next, the normalizer 219 normalizes the autocorrelated value, in step 306. Consequently, the autocorrelation unit 210 outputs a normalized autocorrelated value.

The comparator 222 compares the normalized autocorrelated value to a predetermined threshold value, in step 308. The peak flat detector 224 detects a section where the normalized autocorrelated value is equal to or greater than the threshold value, as a flat section as shown in FIG. 4B, in step 310. The peak flat detector 224 can detect as a flat section a section where the difference or ratio between the autocorrelated value and the threshold value is greater than a predetermined value. Alternatively, the peak flat

detector 224 can detect as the flat section a section having a predetermined sample length after a point where the auto-correlated value is greater than the threshold value. Also, alternatively, the peak flat detector 224 can be made up of an addition unit (not shown) and a flat section detection unit (not shown). The addition unit calculates the sum of a predetermined number of samples after a point where the autocorrelated value is greater than the threshold value. The flat section detection unit (not shown) detects a section where the difference or ratio between the sum and the threshold value is greater than a predetermined value.

The frequency offset estimator 226 estimates a frequency offset within the flat section to obtain a frequency offset value, in step 312. Here, frequency offset estimation can be performed at an arbitrary point within the flat section, so that it allows an error of about ±16 samples. The frequency offset estimator 226 also outputs a mode control signal **mode_ctrl** received by the mode selection unit 20, when estimation of a frequency offset value is completed. In this way, the frequency synchronization unit 22 obtains a frequency offset value by estimating a frequency offset within a flat section.

Alternatively, the frequency offset estimator 226 can be made up of a frequency offset calculation unit (not shown)m and an averaging unit (not shown). The frequency offset calculation unit calculates a plurality of frequency offset values within a flat section two or more times. The averaging unit obtains an averaged frequency offset value by calculating the average of the plurality of frequency offset values, and outputs the averaged frequency offset value as a final frequency offset value.

Following this, the mode selection unit 20 concludes the frequency synchronization mode in response to the mode control signal and selects a symbol timing synchronization mode.

The frequency offset compensation unit 23 performs frequency offset compensation on a received signal using the final frequency offset value obtained by the frequency synchronization unit 22.

The reference signal generator 242 generates and outputs a reference

signal, and the complex conjugator 244 complex-conjugates the reference signal. The multiplier 246 multiplies the complex-conjugated reference signal by the frequency offset-compensated signal output from the frequency compensator 23, and the moving average calculator 248 calculates a moving average. That is, a cross correlated value is obtained by cross correlation performed by the multiplier 246 and the moving average calculator 248. The normalizer 249 normalizes the cross correlated value output from the moving average calculator. In this way, the cross correlation unit 24 performs cross correlation using the frequency offset-compensated signal and the reference signal and normalizes a cross correlated value, thereby outputting a normalized cross correlated value.

The symbol timing synchronization unit 25 detects a point where the cross correlated value is maximum, as shown in FIG. 4C. At this time, an accurate maximum point can be estimated since a received signal has been frequency-compensated. Thus, symbol timing estimation is performed using the accurately-estimated maximum point, thereby reducing symbol timing errors.

As described above, in the symbol timing and frequency synchronization apparatus and method according to the present invention, frequency synchronization and symbol timing synchronization are sequentially performed, and an error of about ±16 samples is allowed. That is, a large sample error can be allowed, so that accurate frequency synchronization can be achieved. Also, symbol timing estimation is performed using an accurately-estimated maximum point, thereby reducing a symbol timing error.

As described above, in the symbol timing and frequency synchronization apparatus and method according to the present invention, accurate frequency synchronization can be achieved because relatively large sample error can be allowed. Also, a symbol timing error can be reduced since symbol timing synchronization is achieved using a frequency offset-compensated signal.

Industrial Applicability

A symbol timing and frequency synchronization apparatus and method according to the present invention is suitable for a wideband wireless LAN which does not require a coarse frequency offset estimation, since a frequency offset that is smaller than a symbol spacing is defined.

What is claimed is:

1. A frequency and symbol timing synchronization apparatus for achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the apparatus comprising:

an autocorrelation unit for receiving data including a synchronizing symbol made up of at least three identical synchronizing signals, delaying the received data by a predetermined delay amount, performing autocorrelation between the received data and the delayed data, normalizing an autocorrelated value, and outputting a normalized autocorrelated value;

a comparator for comparing the normalized autocorrelated value with a predetermined threshold value;

a peak flat detector for detecting as a flat section a section where the normalized autocorrelated value is equal to or greater than the threshold value;

a frequency offset estimator for estimating a frequency offset within the flat section to obtain a frequency offset value;

a frequency offset compensation unit for compensating for the frequency offset of a received signal using the frequency offset value;

a cross correlation unit for performing cross correlation using a frequency offset-compensated signal and a reference signal, and normalizing the cross-correlated value to output a normalized cross-correlated value; and

a symbol timing synchronization unit for detecting a point where the cross-correlated value is maximum, and performing symbol timing estimation, thereby performing symbol timing synchronization.

2. The frequency and symbol timing synchronization apparatus of claim 1, further comprising a mode selection unit for concluding a frequency synchronization mode and selecting a symbol timing synchronization mode.

3. The frequency and symbol timing synchronization apparatus of

claim 1 or 2, wherein the length of the synchronous signal is equal to or less than the length of an OFDM half-symbol.

4. The frequency and symbol timing synchronization apparatus of claim 1, wherein the peak flat detector calculates the difference or ratio of the autocorrelated value and the threshold value and detects as a flat section a section where the difference or ratio is equal to or greater than a predetermined value.

5. The frequency and symbol timing synchronization apparatus of claim 1, wherein the peak flat detector detects as a flat section a section of a predetermined sample length after a point where the autocorrelated value is greater than the threshold value.

6. The frequency and symbol timing synchronization apparatus of claim 1, wherein the peak flat detector comprises:

an addition unit for calculating the sum of a predetermined number of samples after a point where the auto-correlated value is greater than or equal to the threshold value; and

a flat section detection unit for calculating the difference or ratio of the sum and the threshold value and detecting as a flat section a section where the difference or ratio is greater than or equal to a predetermined value.

7. The frequency and symbol timing synchronization apparatus of claim 1, wherein the frequency offset estimator comprises:

a frequency offset estimation unit for obtaining frequency offset values by estimating a frequency offset within the section two or more times; and

an averaging unit for calculating the average of the obtained frequency offset values to obtain an average frequency offset value.

8. A frequency and symbol timing synchronization method for

achieving frequency synchronization and symbol timing synchronization of an orthogonal frequency division multiplexed (OFDM) signal, the method comprising:

(a) organizing a synchronizing symbol with at least three identical synchronous signals;

(b) receiving a signal including the synchronizing symbol, delaying the received signal by a predetermined delay amount, performing autocorrelation between the received signal and the delayed signal, normalizing an autocorrelated value, and detecting as a flat section a section where the normalized autocorrelated value is greater than a predetermined threshold value;

(c) estimating a frequency offset within the flat section to obtain a frequency offset value;

(d) compensating for the frequency offset of the received signal using the frequency offset value;

(e) performing symbol timing synchronization using a frequency offset-compensated signal and a reference signal.

9. The frequency and symbol timing synchronization method of claim 8, further comprising the step of concluding a frequency synchronization mode and selecting a symbol timing synchronization mode.

10. The frequency and symbol timing synchronization method of claim 8 or 9, wherein the length of the synchronous signal is equal to or less than the length of an OFDM half-symbol.

11. The frequency and symbol timing synchronization method of claim 8, wherein in the step (b), the difference or ratio of the autocorrelated value and the threshold value is calculated, and a section where the difference or ratio is equal to or greater than a predetermined value is detected as a flat section.

12. The frequency and symbol timing synchronization method of claim 8, wherein in the step (b), a section of a predetermined sample length after a point where the autocorrelated value is greater than the threshold value, is detected as a flat section.

13. The frequency and symbol timing synchronization method of claim 8, wherein the step (b) comprises:

calculating the sum of a predetermined number of samples after a point where the auto-correlated value is greater than or equal to the threshold value; and

calculating the difference or ratio of the sum and the threshold value and detecting as a flat section a section where the difference or ratio is greater than or equal to a predetermined value.

14. The frequency and symbol timing synchronization method of claim 8, wherein the step (c) comprises:

estimating a frequency offset within the flat section two or more times; and

calculating the average of the obtained frequency offset-estimated values to obtain an average frequency offset value.

FIG. 1A

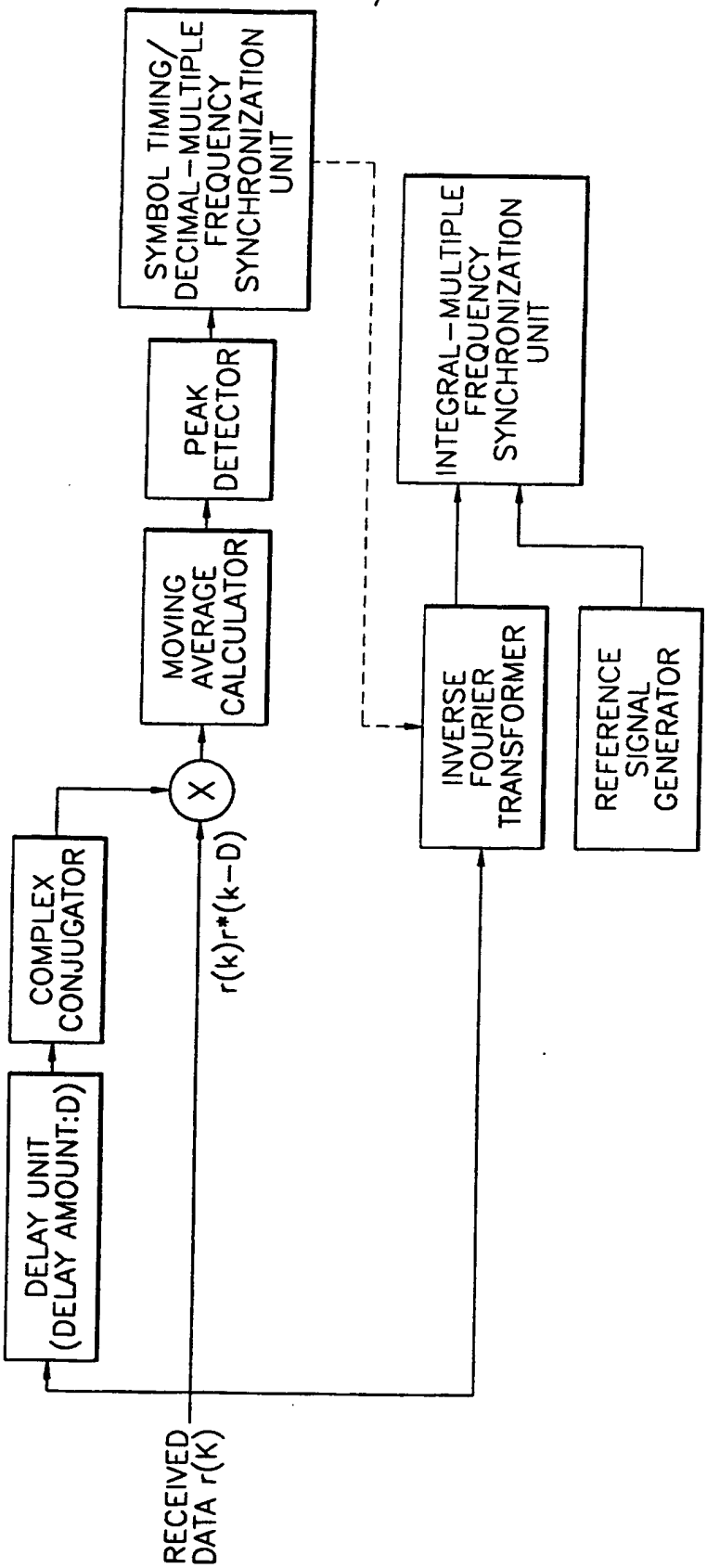

SYMBOL TIMING/ DECIMAL-MULTIPLE FREQUENCY SYNCHRONIZATION UNIT
PEAK DETECTOR
MOVING AVERAGE CALCULATOR
INTEGRAL-MULTIPLE FREQUENCY SYNCHRONIZATION UNIT
INVERSE FOURIER TRANSFORMER
REFERENCE SIGNAL GENERATOR
COMPLEX CONJUGATOR
DELAY UNIT (DELAY AMOUNT:D)
X
r(k)r*(k-D)
RECEIVED DATA r(K)

FIG. 1B

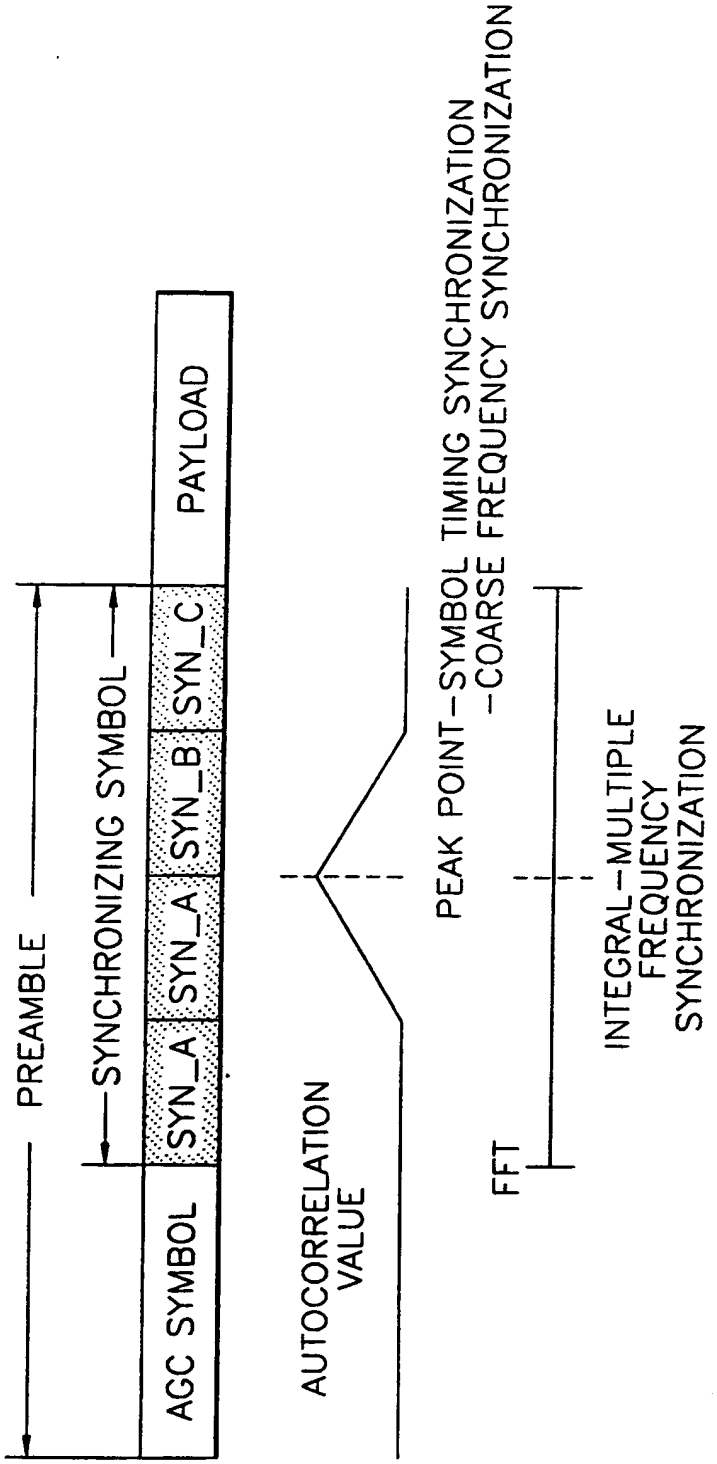

PREAMBLE
SYNCHRONIZING SYMBOL
AGC SYMBOL
SYN_A
SYN_A
SYN_B
SYN_C
PAYLOAD
AUTOCORRELATION VALUE
PEAK POINT-SYMBOL TIMING SYNCHRONIZATION
-COARSE FREQUENCY SYNCHRONIZATION
FFT
INTEGRAL-MULTIPLE FREQUENCY SYNCHRONIZATION

FIG. 2

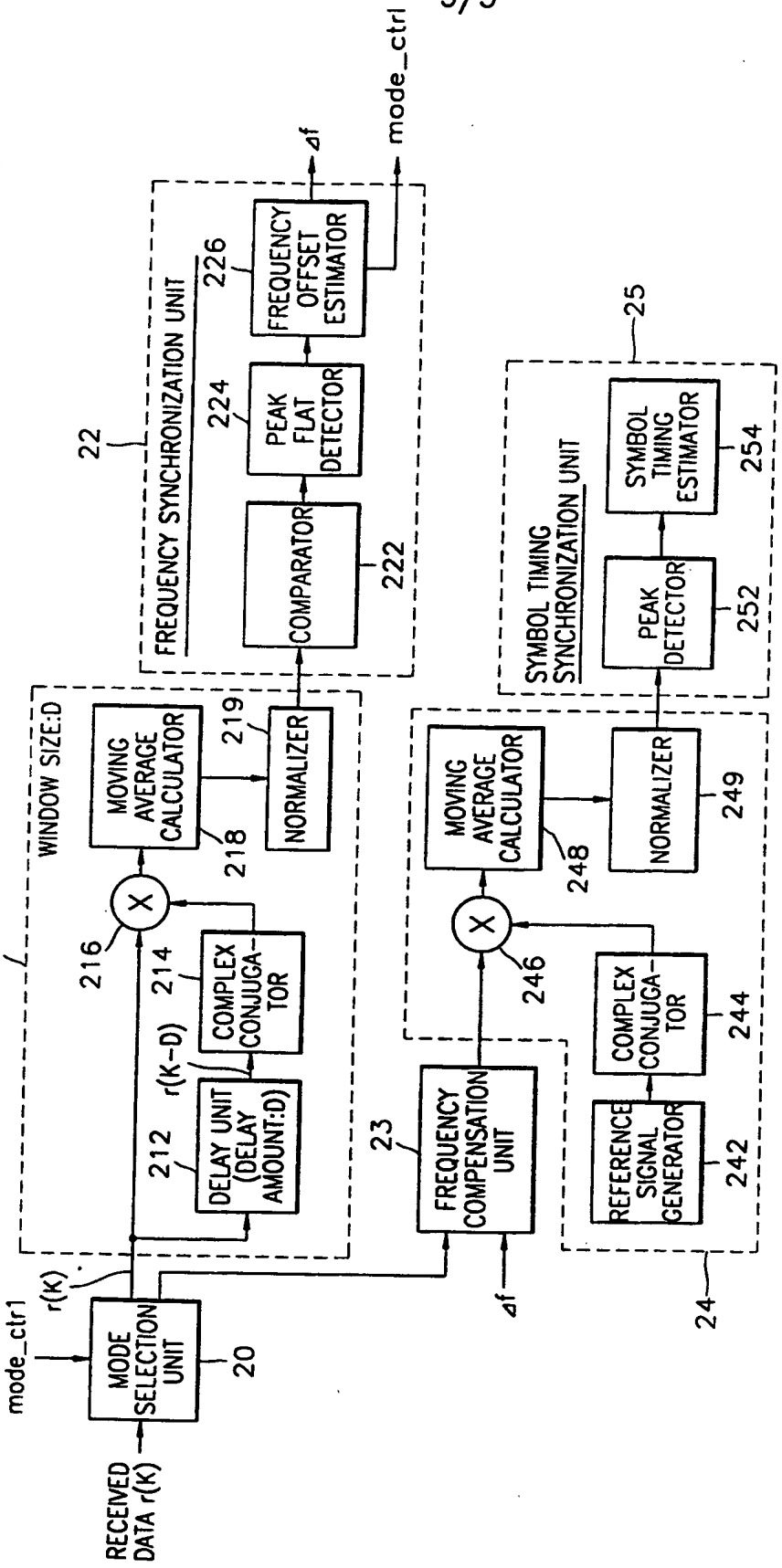
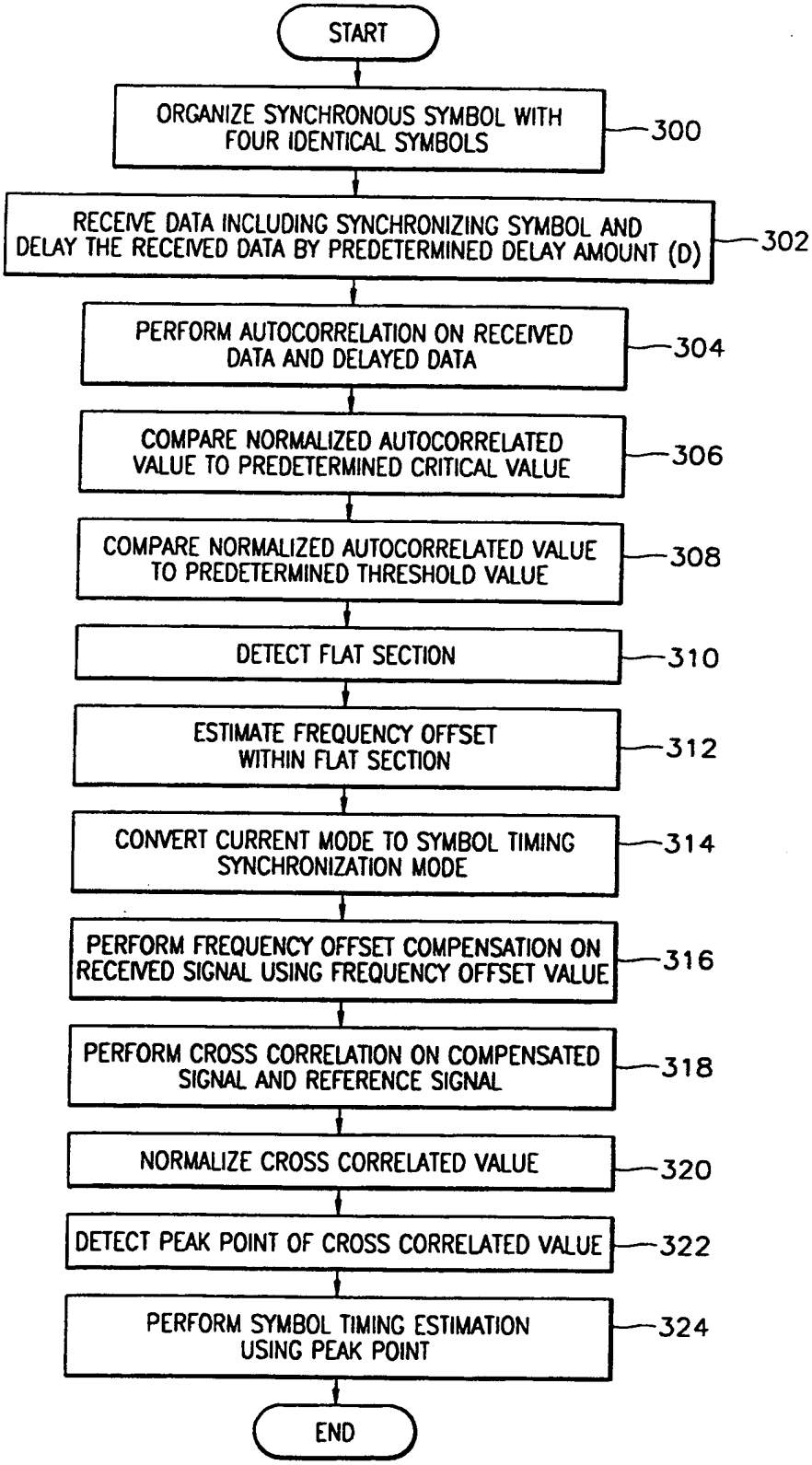

RECEIVED DATA r(K)
mode_ctrl
MODE SELECTION UNIT
20
r(K)
21
WINDOW SIZE:D
DELAY UNIT (DELAY AMOUNT:D)
212
r(K-D)
COMPLEX CONJUGATOR
214
216
MOVING AVERAGE CALCULATOR
218
NORMALIZER
219
22
FREQUENCY SYNCHRONIZATION UNIT
COMPARATOR
222
PEAK FLAT DETECTOR
224
FREQUENCY OFFSET ESTIMATOR
226
mode_ctrl
Δf
23
FREQUENCY COMPENSATION UNIT
Δf
24
REFERENCE SIGNAL GENERATOR
242
COMPLEX CONJUGATOR
244
246
MOVING AVERAGE CALCULATOR
248
NORMALIZER
249
25
SYMBOL TIMING SYNCHRONIZATION UNIT
PEAK DETECTOR
252
SYMBOL TIMING ESTIMATOR
254

FIG. 3


START
ORGANIZE SYNCHRONOUS SYMBOL WITH FOUR IDENTICAL SYMBOLS
300
RECEIVE DATA INCLUDING SYNCHRONIZING SYMBOL AND DELAY THE RECEIVED DATA BY PREDETERMINED DELAY AMOUNT (D)
302
PERFORM AUTOCORRELATION ON RECEIVED DATA AND DELAYED DATA
304
COMPARE NORMALIZED AUTOCORRELATED VALUE TO PREDETERMINED CRITICAL VALUE
306
COMPARE NORMALIZED AUTOCORRELATED VALUE TO PREDETERMINED THRESHOLD VALUE
308
DETECT FLAT SECTION
310
ESTIMATE FREQUENCY OFFSET WITHIN FLAT SECTION
312
CONVERT CURRENT MODE TO SYMBOL TIMING SYNCHRONIZATION MODE
314
PERFORM FREQUENCY OFFSET COMPENSATION ON RECEIVED SIGNAL USING FREQUENCY OFFSET VALUE
316
PERFORM CROSS CORRELATION ON COMPENSATED SIGNAL AND REFERENCE SIGNAL
318
NORMALIZE CROSS CORRELATED VALUE
320
DETECT PEAK POINT OF CROSS CORRELATED VALUE
322
PERFORM SYMBOL TIMING ESTIMATION USING PEAK POINT
324
END

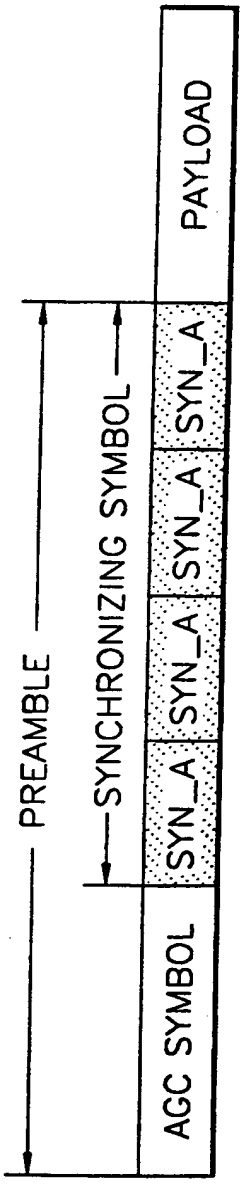


FIG. 4A

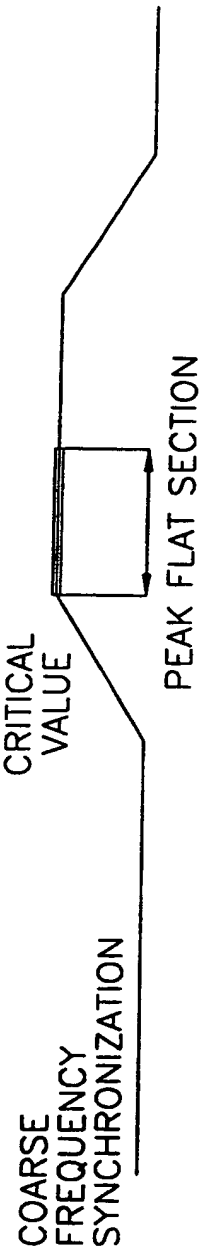


FIG. 4B

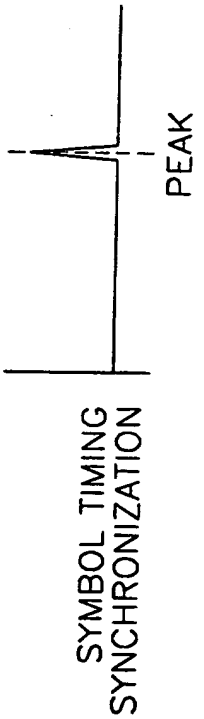


FIG. 4C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR00/00633

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04J 11/00, H04L 7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

KE, JP, US, EP classes as above

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

Korean Patents and applications for inventions since 1975
Korean Utility models and application for Utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

NPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 7-38618(JAPAN RADIO CO. LTD.) 7 FEB 1995 abstract . fig	1, 4, 5
Y	JP 7-297870(MATSUSHITA) 10 NOV 1995 abstract. fig 1	1, 4, 5
A	US 5555247(MATSUSHITA) 10 SEP 1996 abstract, fig 1, 5,10,12,13,14, col. 5, line 46 ~ col. 9, line 25, claim 7,8	1- 7
A	JP 9-247230(MATSUSHITA) 19 SEP 1997 abstract	1- 7
A	JP 10-004401(KOKUSAI ELECTRIC CO. LTD) 6 JAN 1998 abstract	1 - 7

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 OCTOBER 2000 (12.10.2000)	16 OCTOBER 2000 (16.10.2000)

Name and mailing address of the ISA/KR	Authorized officer
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Form PCT/ISA/210 (second sheet) (July 1998)